MASSEY UNIVERSITY

Review of Armed Offenders Squad and Special Tactics Group fitness policy for the New Zealand Police

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science
in
Exercise and Sport Science

at Massey University, Wellington, New Zealand.

James Alexander Dickie

2015

Dr. Sally Lark

Dr. James Faulkner

Dr. Matthew Barnes

ABSTRACT

Phase One: Web based survey questionnaire.

Recruitment into the New Zealand Police's Armed Offenders Squad [AOS] and Special Tactics Group [STG] depends on successful completion of selection courses, as detailed in their respective physical fitness policies. Importantly, these physical assessments must be justified as being relevant and representative of the necessities of job duties. Therefore, as part of a review of the physical fitness policies of the AOS and STG of the New Zealand Police, Phase One of this research sought to objectively determine similarities and relationships between the AOS and STG, and the relevance of physical selection tasks utilised. A web-based survey questionnaire was developed to: 1) provide a demographic profile of the AOS and STG; 2) identify why candidates chose to participate in selection; 3) identify potential barriers for gaining entrance into the AOS and STG; 4) identify physical preparation methods for selection tests; 5) identify troublesome tests; and 6) establish the validity between fitness assessments and the perceived relevance of job demands. A total of 179 AOS (N = 298) and 35 (N = 38) STG members volunteered to participate in the on-line survey document. The main findings revealed that the 12 minute bridge test had the lowest perceived relevance of all selection tests, while the rope pull-up had moderate perceived relevance but was coupled with a high failure rate. This provided evidence to further research the aforementioned assessments in Phase Two of this project.

Phase Two: Analysis of the rope pull-up and twelve minute rotational bridge.

The rope pull-up and 12 minute bridge test are physical assessments utilised to identify whether STG members possess appropriate levels of physical fitness required to perform their role. Due to a lack of empirical research, and Phase One findings, this study sought to: 1) determine whether the rope pull-up is a suitable assessment tool to assess operational climbing ability; and 2) determine whether the 12 minute rotational bridge test is a safe and suitable assessment of core endurance. Nineteen STG members (mean ± SD; 40 ± 5 y, 184 ± 5 cm, 93.6 ± 7.4 kg, 25.4 ± 1.9 kg·m^2) volunteered to participate in this research. Surface electromyography was utilised to measure peak muscle activity of the brachioradialis, biceps brachii, mid-deltoid, upper pectoralis major, mid-trapezius, lower trapezius, latissimus dorsi and infraspinatus during rope pull-up, ladder climb and rope climb tasks. Average muscle activity and signal frequency of the rectus abdominis, external oblique, internal oblique, mutlifidus, lumbar erector spinae, thoracic erector spinae, latissimus dorsi and mid-deltoid were measured during the 12 minute bridge test. Results revealed significantly higher activation of the pectoralis major during the ladder climb when compared to the rope pull-up (81.2 vs. 47.1 %MVIC), and of the pectoralis major (102.6 vs. 47.1 %MVIC) and infraspinatus (81.9 vs. 57.4 %MVIC) during the rope climb, when compared to the rope pull-up (all, $P < .01$). Rotation between prone and side positions in the bridge test suitably assessed muscular endurance of all major muscles involved in core stability. No significant differences in signal frequency across each stage, for all muscles ($P > .05$), indicated that muscular fatigue was minimal. Based on the present study, the rope pull-up was deemed non-appropriate to assess operational climbing ability; while the rotational bridge served as a practical endurance assessment of all major muscles involved in core stability, with the 12 minute duration not likely to cause fatigue related injury.

ACKNOWLEDGEMENTS

First and foremost, I would like to acknowledge the invaluable help and guidance provided by my supervisors, Drs. Sally Lark, James Faulkner and Matthew Barnes, who offered up their time and assistance over the past two years. Without their assistance this study would not have been possible. I am also extremely grateful to the New Zealand Police who dedicated their time, resource, and patience into the running of this project. Their trust in my ability not only facilitated this research, but also saw me grow as an individual. I also wish to thank Maria for her love and continued support which provided a stable environment outside of University. I am grateful for the constant encouragement from my parents Angela and Maurice, who inspire me to set high standards. Lastly, I am thankful to all participants who volunteered to participate in this research, without their interest this study would not have been possible.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ACSM – American College of Sports Medicine

ADL – Activities of daily living

ANOVA – Analysis of variance

AOS – Armed offenders squad

ARV – Average rectified variable

BB – Biceps brachii

Blue role – Open water operations

BR – Brachioradialis

BMI – Body mass index

EMG – Electromyography

EO – External oblique

FI – Fatigue index

G. Maximus – Gluteus maximus

G. Medius – Gluteus medius

IO – Internal oblique

IS – Infraspinatus

LD – Latissimus dorsi

L ES – Lumbar erector spinae

LT – Lower trapezius

MD – Mid-deltoid

MT – Middle trapezius

Mul – Multifidus

MVIC – Maximal voluntary isometric contraction

NZ – New Zealand

O_2 - Oxygen

PCT – Physical competency test

PM – Pectoralis major

PCr – Phosphocreatine

RA – Rectus abdominis

RMS – Root mean square

STG – Special tactics group

SWAT – Suburban weapons and tactics

T ES – Thoracic erector spinae

U.S. – United States

VO_{2max} – Maximal oxygen uptake

WP – Wide pronated

WS – Wide supinated

LIST OF TABLES

LIST OF FIGURES

1. RESEARCH BACKGROUND

The New Zealand Police have requested a full review of their required physical fitness policies for the Armed Offenders Squad [AOS] and Special Tactics Group [STG] in order to determine the relevance of physical fitness testing to the job demands. The role of the AOS and STG continues to evolve, but the required physical fitness policy has not been reviewed since its induction in 2004 (New Zealand Police., 2011). As such, the NZ Police have engaged Massey University to undertake the review. The research team consists of James Dickie and Drs. Sally Lark, James Faulkner and Matthew Barnes. James Dickie completed all aspects of this project on behalf of the NZ Police, and to fulfil the requirements of a Master's degree.

The NZ Police is primarily an unarmed force, with major firearms incidents being dealt with by the STG or AOS who are more specifically trained and equipped than general police. The AOS is a part-time response unit who are trained to cordon and contain situations where firearms may be involved. Importantly, the AOS serves as a feeder group into the STG. The STG are a full time, multi-skilled unit who are deployed on numerous roles over and above armed callouts, and including AOS duties. The skills include rappelling from helicopters, ocean swimming and ship boarding, and rural surveillance possibly spanning several days deployed in woodland/forestry areas. Accordingly, STG members require high levels of physical fitness (cardio-respiratory and muscular strength/endurance) and mental attributes. Selection into both the AOS and STG depends on the successful completion of rigorous national selection and qualification courses. Furthermore, in order to retain placement within each group members must also complete annual fitness assessments, as detailed in the respective physical fitness policies (New Zealand Police., 2011).

The following attributes have been identified as key areas associated with successful STG operation: physical competency and coordination; mental acuity; emotional intelligence; technical skills; to be adaptable in an ever changing environment; and to be socially aware (Wood, Cronin, & Hopkins, 2004). The selection courses are designed to test each of these attributes, encompassing pass/fail standards: if one component is failed then the candidate automatically fails the course. The physical fitness policies serve as modus operandi to gain entrance and retain placement within the specialised roles of the AOS and STG.

After careful planning and consideration alongside NZ Police hierarchy, it was determined that the best way to conduct the research would be to split it into two phases. Phase One consisted of a web-based survey questionnaire to examine key areas detailed in the next section. Phase Two involved a comprehensive assessment of specific exercises identified through the survey questionnaire for their lack of apparent relevance to job demands. This thesis is structured in two separate parts relating to the aforementioned phases.

Phase One: Web-based survey questionnaire

2. INTRODUCTION

Occupational fitness is an emerging term among uniformed services, and refers to certain roles requiring physical competencies that are essential for completion of job-specific tasks (Anderson & Plecas, 2007; Pryor, Colburn, Crill, Hostler, & Suyama, 2012). Operational tasks within the AOS and STG of the NZ Police are physically demanding across a range of physical fitness parameters including cardiovascular fitness, muscular strength, muscular endurance and flexibility (Wood et al., 2004). Therefore, a physical fitness policy details the fitness requirements to gain entrance into, and maintain position within the AOS and STG. As with most uniformed services, the physical fitness policy is based upon operational requirements and associated competencies (Payne & Harvey, 2010). Employment policy usually requires equal opportunity for any race, sex or ethnic group as a result of legal requirement (Payne & Harvey, 2010). However, selection procedures can avoid being labelled as discriminatory if they are based on a job analysis, indicative of critical job duties and are justified as necessities of job duties, behaviours or outcomes (Hodgdon & Jackson, 2000). Due to the dangers and risks associated with the work of AOS and STG, it is highly difficult for a researcher to go on deployment to perform a task analysis. Instead, surveys provide a means for data to be gathered to form a job analysis.

2.1. Developing the research question

Phase One of this project sought to objectively determine similarities and relationships between the AOS and STG, and the relevance of physical selection tasks utilised. Non-experimental designs enable naturally occurring relationships and behaviours amongst populations to be objectively measured, suiting this phase of the research project (Creswell, 2002; Matthews & Kostelis, 2011). Identifying the purpose of conducting survey research is a fundamental first step in developing the questionnaire (Dolnicar, 2013; Turocy, 2002). This process guides the questions to be asked in the survey by identifying the variables that need to be assessed.

In this research, the web-based survey questionnaire sought to gather data in relation to:

1) Basic demographics of current AOS and STG members.
2) Underpinning reasons for why individuals participated in the selection tests.
3) Potential barriers to joining the AOS and STG.
4) Whether candidates sufficiently prepared for the selection tests.
5) Physiological competencies where candidates may be failing.
6) The validity between the tests in the selection courses and annual fitness assessment, to the perceived relevance of job demands.

3. LITERATURE REVIEW

3.1. Surveys for task analysis

Traditionally, police tests have followed a military approach to fitness (Copay & Charles, 1998); however, without modification these can be injurious and lack justification for their specific use to law enforcement occupations. This poses the research question; is the current NZ Police AOS and STG fitness testing relevant to the job demands? Due to lack of evidence in this area specific to the NZ Police AOS and STG the relevance of physical fitness tests must be further investigated.

Previous research details that common tasks performed by the AOS and STG must first be identified, allowing the relevance of the current testing policy to then be determined (Lee & Clark, 1997; Rayson, Holliman, & Belyavin, 2000). The Canadian Police successfully utilised survey research to analyse the relevance of the physical abilities required to meet job demands (Figure 3.1) (Anderson & Plecas, 2007). Based on the survey answers, the authors were able to allude to which performance tasks would be most suitable to replicate the job requirements. However, in order for physical testing to be relevant to a job, a definition of the tasks associated with the role must be established, prior to determining an individual's occupational fitness (Bonneau & Brown, 1995; Peterson, Rhea, & Alvar, 2005; Rayson, 2000).

A small scale study of an American SWAT team identified a requirement for aerobic fitness, limb strength, core strength, flexibility and muscular power by performing a task analysis (Pryor et al., 2012). However, the study also revealed that although the SWAT member's level of muscular strength was good, they lacked the aerobic fitness, flexibility and power needed to adequately perform their role (Pryor et al., 2012).

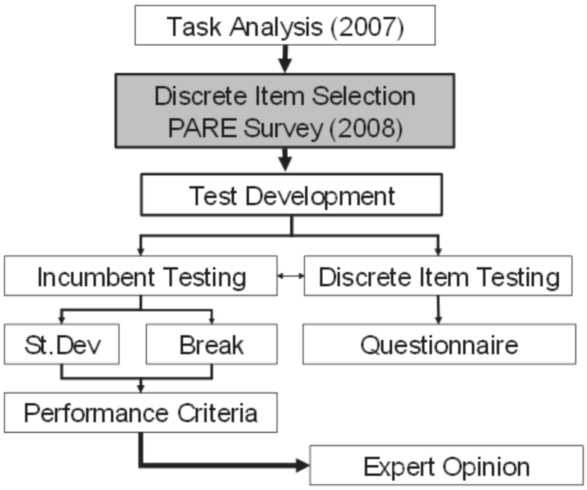

Figure 3.1. Bona fide occupational requirement test development overview. Retrieved from: Anderson, A. S., & Plecas, D. B. (2008). *Physical abilities requirement evaluation (PARE), phase 2: discrete item analysis*, p. 5. Abbotsford, BC: University College of the Fraser Valley.

A study performed by Lee and Clark (1997) utilised a survey questionnaire to identify key tasks performed by solders in the Canadian Forces. The survey required participants to rank a list of tasks according to the demand to perform them; the tasks were identified by experts within the Canadian Forces (Lee & Clark, 1997). The research determined whether the physical fitness requirements were representative of job demands and associated physical fitness parameters, by identifying the most commonly performed tasks. Similarly, survey questionnaires have been used in conjunction with observation to determine the job specific requirements of front-line police officers in British Columbia (Anderson, Plecas, & Segger, 2001). Statistical analysis of the survey identified specific tasks commonly performed by the front-line officers, which was then used to re-validate their selection criteria (Anderson et al., 2001). Similarly, the British military were surveyed for the most commonly performed tasks and the level to which these tasks needed to be performed (Rayson et al., 2000). This extant research justified the chosen method for Phase One of this research.

It is evident that by identifying tasks performed by a specific role within the uniformed services, more relevant physical fitness policy can be applied (Anderson et al., 2001; Copay & Charles, 1998; Lee & Clark, 1997; Pryor et al., 2012; Rayson, 2000; Rayson et al., 2000). The aforementioned research utilised survey tools designed to assess the roles of frontline police staff, whereas this research seeks to examine tactical operations of policing. Due to the unique geography of New Zealand, members of the AOS and STG are often required to perform roles in challenging terrain, including bush surveillance and coastal deployments. Hence, differences in job requirements exist between the NZ Police and previous research, meaning direct comparison cannot be made (Pryor et al., 2012; Rayson et al., 2000). The lack of research specific to the NZ Police AOS and STG, and their evolving role, highlights the need for further investigation of job requirements in order to determine the relevance of current physical fitness policy. This research will form the basis to either validate current testing deemed relevant, or to give evidence supporting the possibility of modification to the policy.

3.2. Developing the questionnaire

As we sought to develop a unique survey questionnaire for the NZ Police AOS and STG a review of data acquisition and analysis methods was performed. The content of a survey is crucial in obtaining useful information that can be statistically analysed (Dolnicar, 2013). The researcher must define what is being measured, how many questions to ask, how to ask the questions and what format should be used for responses (DePoy & Gitlin, 2011; Dolnicar, 2013; Sinkowitz-Cochran, 2013). The content of the survey depends on the research question, and is derived from reducing the question into important, measurable parts (Kirshner & Guyatt, 1985). Inclusion items may be derived from literature reviews, interviews or focus-group sessions from ‘experts’ within the target population (Burns et al., 2008). It is typical for most quantitative surveys to contain closed-ended questions, such as nominal responses, ordinal responses or interval and ratio measurements (Burns et al., 2008). The survey should be free of bias, non-judgemental, easy to understand and highlight the most important constructs (Burns et al., 2008; Corbetta, 2003).

When choosing the type of survey to administer it is important to acknowledge each of their strengths and weaknesses. Face-to-face surveying has the highest response rate but is the most time consuming, whilst web-based surveying is the least time consuming but has the lowest response rate (Krosnick, 1999; Matthews & Kostelis, 2011). Hence, the technique chosen must be considered in relation to the research question and the target population, as well as time and budget constraints.

3.2.1. Demographic and behavioural questions

Surveys usually involve a collection of some demographic type data, allowing the researcher to identify relationships between demographic characteristics of respondents and certain variables (Fernandes et al., 1999; Schmidt, 1997; Turocy, 2002). Behavioural questions may also provide an understanding of training habits/tendencies in preparation for certain events, or changes in habits/tendencies once a change in lifestyle or career has been made (DePoy & Gitlin, 2011; Krosnick, 1999; Turocy, 2002). Demographic and behavioural type questions are usually asked in a closed-ended response format whereby respondents choose their answer from an exhaustive list of items (Dolnicar, 2013; Turocy, 2002). This format allows for answers to be easily coded for statistical analysis as there is consistency in responses (DePoy & Gitlin, 2011; Matthews & Kostelis, 2011; Turocy, 2002). Specifically to the NZ Police, these types of questions will allow identification of any differences between the AOS and STG, and whether these differences may influence the respondents desire to progress onto the STG.

3.2.2. Likert scales

The Likert (1932) scale is an extremely popular survey response format, allowing each respondent to rate their overall perception of a particular belief, attitude, or characteristic in an ordered system (Turocy, 2002). The scale allows respondents to rate a question on a continuum (usually between 5-7 points) which has descriptive cues (Sinkowitz-Cochran, 2013). This type of response format is easily interpreted and quick to answer (Dolnicar, 2013). It has been shown that scales with more than five points offer no greater efficacy due to a definitive levelling off in reliability at this point (Lissitz & Green, 1975); therefore, the Five-point Likert scale is the most widely utilised (Foa, Riggs, Dancu, & Rothbaum, 1993; Hopmans et al., 2013; Parkes, Caravale, Marcelli, Franco, & Colver, 2011; Scandura, 1992; Voorn et al., 2013). This method of data acquisition could be beneficial in determining respondent's perceived relevance of physical fitness components, perceived relevance of physical selection tests to job demands, and how often they perform job specific tasks.

3.2.3. Ranking scales

Ranking scales allow respondents to rank their attitude toward a certain variable by level of preference (Phillips, Johnson, & Maddala, 2002; Sinkowitz-Cochran, 2013). They are suitable to use in self-administered surveys due to the simplicity to understand (Kinnear & Taylor, 1996). This type of question can add beneficial information to a survey, not achievable with the use of rating scales (DePoy & Gitlin, 2011; Matthews & Kostelis, 2011). However, one drawback of ranking scales is that regardless of the participant's outlook, a ranking of variables still takes place (Ahlstrom & Westbrook, 1999; Kinnear & Taylor, 1996). Specifically to this research, the ranking scale was used to identify the preference of STG location, which selection tasks were the most difficult/easiest, and which selection tests were trained most/least for.

3.2.4. Open-ended questions

Open-ended questions shift the power from the researcher to the participants, helping to improve response rates as the participants feel they have meaningful input to the survey (Burns et al., 2008; Christensen, 2007). This provided an opportunity for subjective feedback in which continually occurring themes, ideas or unintended answers may relate back to the research question, thus allowing terminology to be analysed (DePoy & Gitlin, 2011; Sinkowitz-Cochran, 2013). For this reason, open-ended questions were added into the survey questionnaire.

3.3. Response rates

Surveys allow large populations to be researched and are generally inexpensive compared with other quantitative methods. Mail based surveys generally have slightly higher response rates than web-based surveys but both seem to elicit a response rate ranging between 50-60 % (Berg et al., 2005; Krosnick, 1999). It is important to gain the highest possible response rate to minimise bias and ensure that the sample represents the target population. A 70 % response rate is usually considered optimal to maintain external validity (Henry & Zivick, 1986; Matthews & Kostelis, 2011; Rubenfeld, 2004); while Portney and Watkins (2000) maintain that anything between 60-80 % is excellent. It has been shown that sending up to three reminders to all non-respondents will maximise response rates (Burns et al., 2008; Sinkowitz-Cochran, 2013; VanGeest, Johnson, & Welch, 2007).

3.4. Validity

The content of the survey is integral to ensure that validity is maintained. Internal validity implies that the chosen method can be replicated and yield similar statistical results, resulting in the research question being properly answered (DePoy &

Gitlin, 2011; Kirchgassler, 1991). Survey methodology constitutes a strong internal validity by assessing: face; content; construct; and criterion validity. These can be controlled through: subjective and expert analysis of the questionnaire; pre-testing of the survey instrument; ensuring that measured behaviours and experiences relate to key constructs underpinning the questions; and by comparing the survey tool against one with proven validity (Burns et al., 2008; Corbetta, 2003; DePoy & Gitlin, 2011).

3.5. Data analysis

Survey literature often includes the reporting of mean, median, mode and standard deviation; in addition to percentages and correlational values to determine associations (Corbetta, 2003; Heerwegh & Loosveldt, 2008; Krosnick, 1999; Phillips et al., 2002). Ultimately this data gives an objective measure describing the relationships between the predefined variables in the survey questions, and will enable the researchers to answer the research questions for this phase of the project; as detailed in the methodology section.

3.6. Focus of the present study

As mentioned earlier in the literature review, survey research has been successfully utilised to perform job analysis of various unformed services, including international Police Forces. However, due to the unique environment New Zealand presents, a survey tool needed to be developed specific to the roles of the NZ Police AOS and STG. Although a unique survey questionnaire was developed, the survey content, question formats and analysis methods were informed by the previously discussed research methods. It was then expected that analysis of the data would highlight particular areas of testing that require further investigation.

4. METHODOLOGY

The development of our inclusion items for the questionnaire was predominately informed by the physical fitness policy written by NZ Police for the AOS and STG (New Zealand Police., 2011); along with supplementary input from expert members of the police hierarchy.

4.1. Participants

The entire AOS and STG populations were asked to participate in the on-line survey. This included a total of 362 NZ Police men and women currently serving with the STG (N = 38), AOS (N = 298) or who attempted and failed AOS selection (N = 26). Inclusion criteria required all participants to be either current members of the STG or AOS, or to have attempted and failed AOS selection (within the last five years) but who are still serving the NZ Police. The present research was conducted under the Massey University low risk ethics guidelines and policies (see Appendix A).

4.2. Survey procedures

As this study involves members of the NZ Police who are spread widely across the entire country, the online method was the chosen means for distribution of the survey. A census of the target population was obtained from the NZ Police database. An email containing a cover letter (see Appendix B), and link to the survey was sent by the researcher to all those meeting the inclusion criteria. The covering letter stated that participation was entirely voluntary and that completion and ‘return of the questionnaire implies consent’. The survey questionnaire was created with Google documents (Google, Mountain View, CA). The survey link sent to each participant opened the survey questionnaire, which was supported online by Google drive (Google, Mountain View, CA). All information remained anonymous and no identifiable information (such as name, exact age etc.) was gathered. Upon submitting the questionnaire, data was automatically uploaded to a spreadsheet only accessible by the researcher. Participants could not access others responses. The survey was open for completion over seven weeks. During this period members of the AOS and STG were contacted by email on four separate occasions to maximise response rates: the initial email and three follow up emails sent fortnightly (Burns et al., 2008; Sinkowitz-Cochran, 2013; VanGeest et al., 2007).

4.3. Questionnaire design

All questions were informed by the physical fitness policy, and research brief presented by the NZ Police. To ensure that content validity was maximised the questions were developed with guidance from a three person supervisory team, along with expert knowledge from the police hierarchy, including the physical education officer who developed the testing protocol. The survey was designed to ascertain demographic profiles of the AOS and STG, identify training tendencies and behaviours, identify the frequency of job specific tasks on deployment, and determine the relevance of physical selection tests to the job requirements of the respective roles. The survey was estimated to take between 15-20 minutes to complete with 52-74 questions (dependent on answer selection) for AOS; and 20-30 minutes with 104-128 questions (dependent on answer selection) for STG members (see Appendix C for a copy of the survey). In addition, a separate survey approximately five minutes long and containing 9-12 questions was sent to those who had attended and failed AOS selection (see Appendix D). This small questionnaire sought to identify areas where candidates were failing in addition to training tendencies and behaviours. During selection courses candidates are also assessed on their competency to fulfil the role of the AOS and STG with written exams, and scenario testing. Likewise to physical assessments, candidates will not be accepted into the AOS or STG if they fail these areas.

The main survey was split into the following three main sections and subsections:

1. Demographics
2. AOS specific sample
    - aspiration to progress onto the STG
    - training tendencies and behaviours
    - relevance of selection tests to the AOS role
3. STG specific sample
    - training tendencies and behaviours
    - the physical demands of the role
    - how often they perform job specific tasks
    - relevance of selection tests to the STG role

Due to selection policy into the STG, all STG members are required to have experience with the AOS, and therefore answered all three sections of the survey. The AOS were not asked questions pertaining to the physical demands of the role, or the frequency of performing job specific tasks, as the research objectives sought to ascertain perceived relevance of currently utilised testing procedures. Responses in the demographic section, and aspiration and training behaviours/tendencies subsections were asked in a closed-ended format (Dolnicar, 2013; Turocy, 2002). Conversely, some training behaviour and tendency questions required respondents to rank variables on a scale (Phillips et al., 2002; Sinkowitz-Cochran, 2013). The subsections of physical demands, how often they perform job specific tasks and relevance of selection tests were all answered on a Five-point Likert (1932) scale, with 1 representing the negative and 5 representing the positive ends of the continuum. Descriptive cues of “not demanding” “very demanding”, “not often” “very often”, or “little relevance” “high relevance” were provided at each end of the scale (DePoy & Gitlin, 2011; Sinkowitz-Cochran, 2013). Open-ended questions such as: *“do you perceive the STG to be an appealing role within the police force? Please state why”* and *“are there any changes you would suggest be made to the AOS selection course?”* were also asked. All questions in the additional survey for those who had attempted and failed AOS selection were asked in a closed-ended response format.

Subjective analysis of the survey by the research team was utilised to ensure face validity was maintained. Additionally, four experts from the NZ Police hierarchy assessed and pre-tested the survey instrument in order to ensure content validity was being maintained. This process also identified that all questions related to the constructs underpinning each question, and ensured that the questions were clear and concise, and that the format was easy to follow (Kelley, Clark, Brown, & Sitzia, 2003).

4.4. Data analysis

Data submitted via the survey was downloaded from an online survey response form. All nominal and ordinal data was first coded using Office Excel (Microsoft, Redmond, WA), then analysed using the statistical analysis programme SPSS version 22.0 (IBM, Armonk, NY). Examples of numerical codes utilised included:

Yes = 1, No = 2;

STG = 1, AOS = 2;

European = 1, Māori = 2, Samoan = 3.

A series of independent samples t-tests were used to analyse differences between members of the AOS and STG; Levene’s test was used to assess the equality of variance with significance set at 5 % ($P \leq .05$). Measures of central tendency and frequency distribution were also utilised for descriptive analysis.

5. RESULTS

5.1. Response rate

A total of 336 AOS and STG members (100 % of the population) were asked to participate in the survey, with 214 respondents giving a 63.7 % total response rate. The AOS members (N = 298) had a relative response rate of 60.1 % (n = 179); while the STG members (N = 38) had a relative response rate of 92.1 % (n = 35).

5.2. Demographics

The combined AOS and STG population were predominately male (97.6 %) with 94.4 % being married or in a relationship and having an average of 2 ± 1 children. The majority of the population was Caucasian (83.2 %), followed by Māori (15 %); 4.7 % could speak Māori, 0.9 % could speak Samoan and 3.3 % another language. A total of 89.7 % of the combined group identified as being homeowners. Education data showed that 5.2 % had no secondary school qualification, while the highest level of secondary education attained was level one (5^{th} form) (11.7 %), level two (6^{th} form) (35 %) and level three (7^{th} form) (48.1 %). Furthermore, just over half (50.5 %) had some form of tertiary education with 28.5 % having a diploma, 18.7 % a bachelor's degree and 1.9 % a master's degree. There were no significant differences (P > .05) in the demographic profile of the AOS and STG.

All AOS members were divided into current city of residence and then grouped on whether or not they would consider moving to an STG location. From the North Island minor cities/towns a much larger proportion of AOS members stated that they would not move to an STG location (36.8 %), compared with South Island minor cities/towns (13.7 %). However, 34.6 % of respondents from North Island minor cities, and 22.2 % from South Island minor cities stated that they would move. There was no

STG location that stood out as a preferred location with Auckland, Wellington and Christchurch receiving 34.1 %, 37.5 % and 28.4 % as first choice city respectively. It is important to note that 54.7 % of all AOS members indicated that they would not move location.

Statistically there were no significant differences in the age distribution of the two groups (P = .36). However, Figure 5.1 identifies that the majority of members in both groups are ≥ 38 years of age, especially the STG with 77.2 % of all operators being ≥38 years of age.

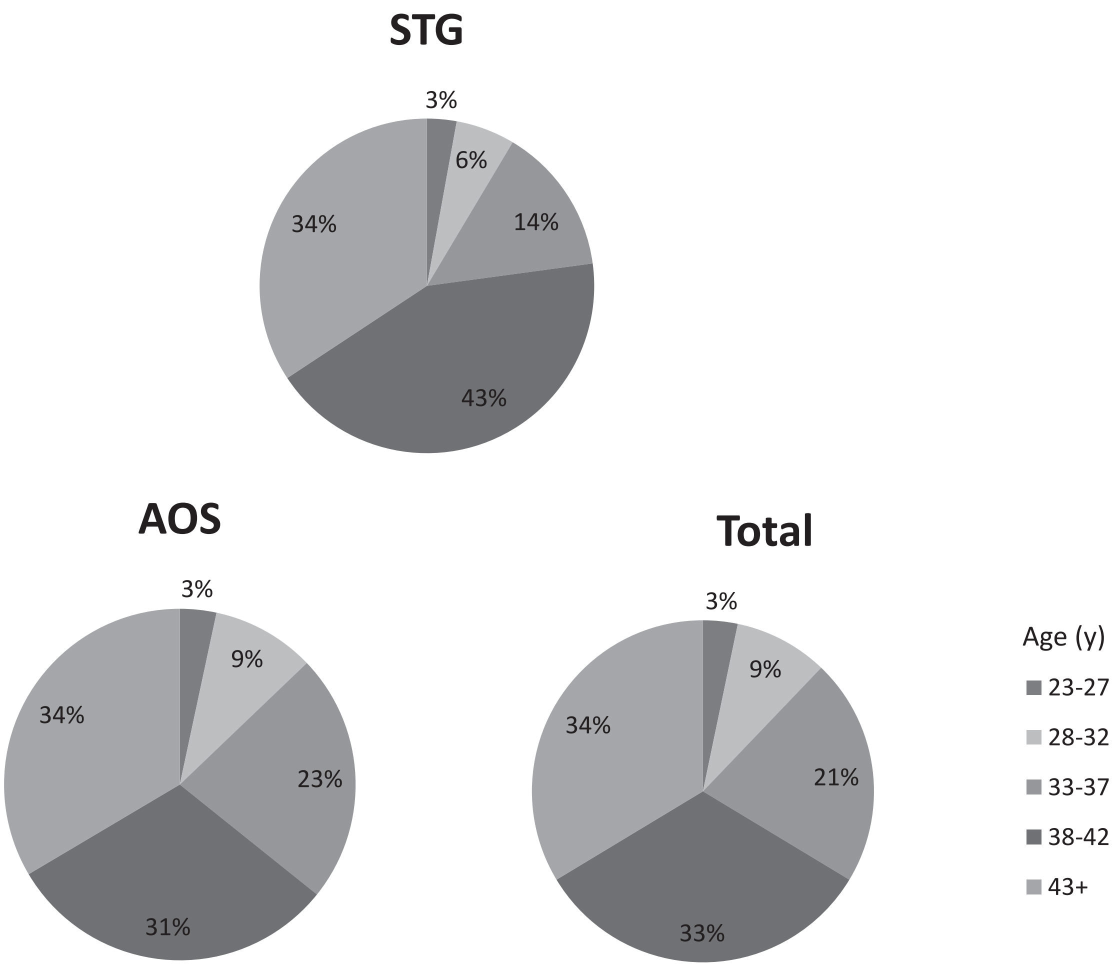

Figure 5.1. Age distribution of the AOS and STG populations.

5.3. AOS specific sample

5.3.1. Aspiration to progress onto the STG

Of all AOS members, 47.4 % perceived that participation within the STG would inhibit their career development within the police ranks. A total of 65 % of officers had no aspiration to progress to STG prior to selection into the AOS, however, this declined to 45.5 % once they became members of the AOS. The most notable theme negatively influencing aspiration to progress onto the STG was the impact such a role would have on family/children, this is also shown in Figure 5.2.

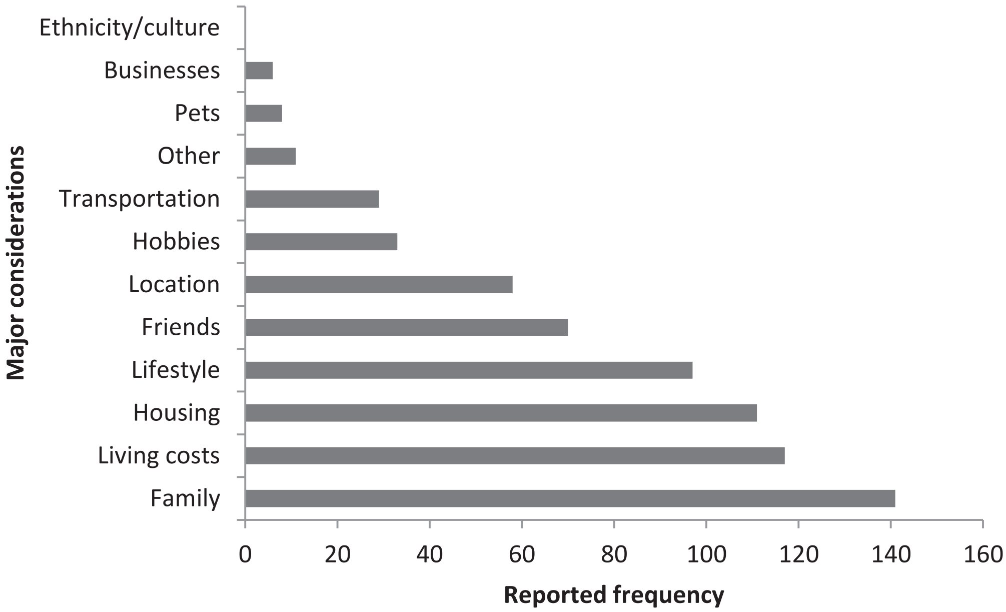

Figure 5.2. Frequency of major considerations about moving from current residence to one of the STG locations.

5.3.2. Training tendencies and behaviours

A total of 33.5 % of all officers took an average 3 ± 1.9 weeks leave to train for the AOS selection course. Of those who took leave, 88.4 % of this leave was paid. An estimated 20.8 % of officers spent 1-4 weeks training specifically for AOS selection; 18.8 % spent 5-8 weeks training; 25.5 % spent 9-12 weeks training and 13.5 % spent 13-16 weeks training. Figures 5.3a, 5.3b and 5.3c show the weekly hours spent training prior to nomination for AOS selection, whilst training specifically for AOS selection and once a member of the AOS. There were no significant differences in the weekly training tendencies of the AOS and STG ($P > .05$).

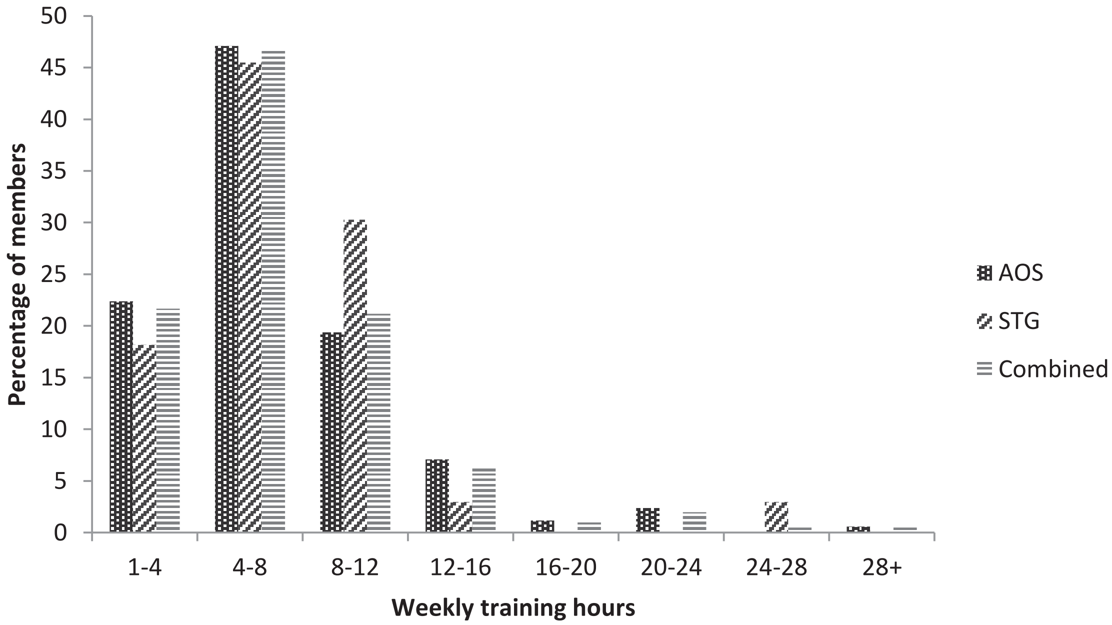

Figure 5.3a. Average weekly training hours prior to nomination for the AOS selection

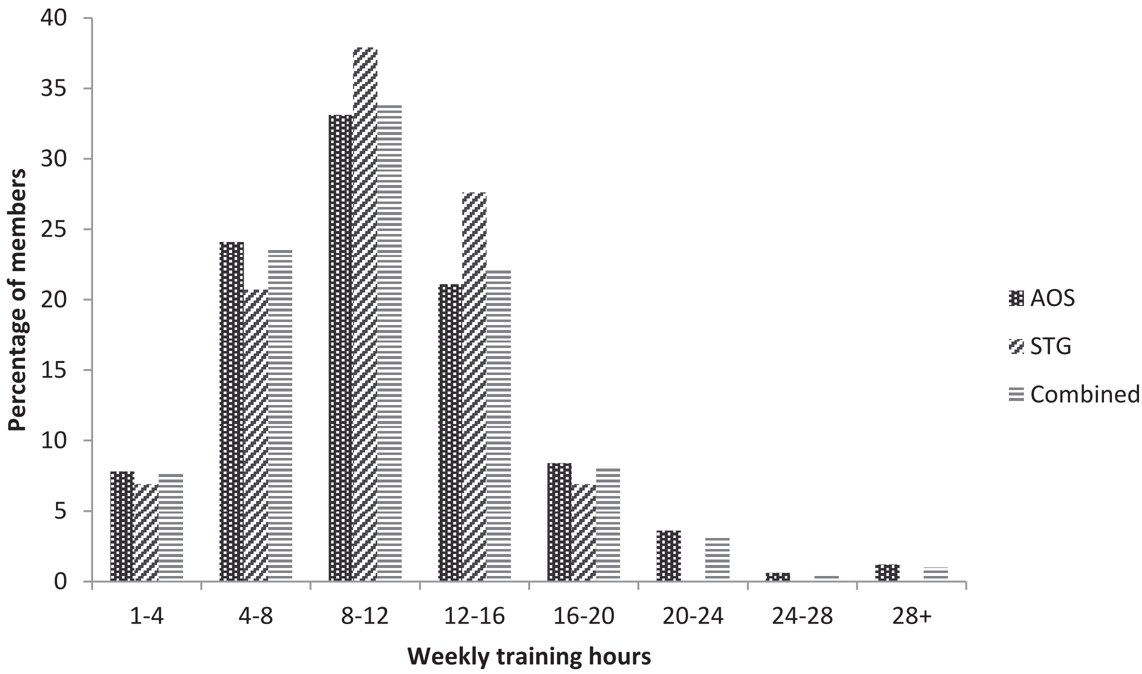

Figure 5.3b. Average weekly training hours whilst training specifically for AOS selection course.

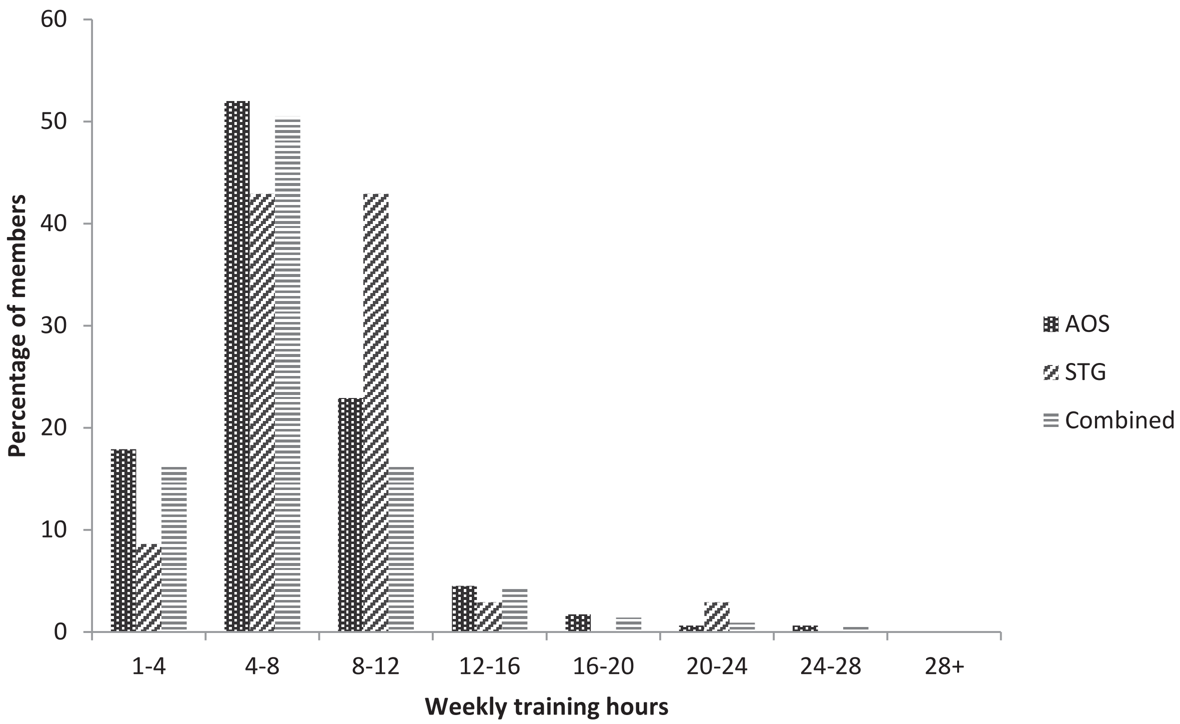

Figure 5.3c. Average weekly training hours once an AOS member.

Overall, 85.6 % of AOS and STG members felt that their training regime was correct leading up to the AOS selection, whilst only 53.2 % were provided with training advice or a training programme for their preparation. Furthermore, there was no significant difference (P > .05) whether they were from a major city (Auckland, Wellington, Christchurch) or a North/South Island minor city and whether or not they received training advice. Both the AOS and STG members thought it beneficial for the AOS to have a more specific annual fitness assessment; however, those with longer training hours perceived it was more beneficial to have a more specific annual assessment, compared with those training less hours (P = .058).

Of all AOS members, 8 % sustained an injury as a result of training for the AOS selection course. This figure increased to 16.4 % when performing AOS maintenance training. Although the calf/ankle area (39.5 %), knee (25.6 %) and back (7 %) were the most commonly reported injury sites, 48.8 % of all injuries were muscle strains.

When asked to rate their current level of fitness on a Five-point Likert scale (1 = less fit, 3 = the same, 5 = more fit) since first passing the AOS selection course, the current AOS members scored 2.81 indicating that fitness levels had slightly decreased. The STG members scored 3.97 signifying they were more fit since first passing AOS selection.

5.3.3. Relevance of selection tests to AOS role

Table 5.1 details subjective information about the perceived relevance of AOS selection tests to the demands of the job. In addition to the components of the test that were most or least trained for, and the components that participants found the most difficult or easiest.

5.3.4. American College of Sports Medicine [ACSM] fitness components

Out of the five components of physical fitness defined by ACSM (ACSM, 2010), participants perceived cardiovascular fitness as having the greatest relevance of all physical fitness components to the job demands (4.33 ± 0.72), followed by muscular endurance (4.29 ± 0.73), muscular strength (3.9 ± 0.80), body composition (3.55 ± 1) and finally, flexibility (3.5 ± 0.93).

5.3.5. Failed STG selection

There were 10.7 % respondents within the AOS and STG samples that had attempted and failed the STG selection course. Of those who failed, 68.2 % thought the selection course was fair, with 65.2 % stating that they would reapply. The activities resulting in failure were rope pull-ups (17.4 %), and the M4 shoot (17.4 %), while 13 % sustained an injury and could not complete.

Table 5.1. Perceived relevance of the AOS selection tests to the role of an AOS member, as well as the tests most or least trained for and the tests found easiest or most difficult.

		Little		Relevance		High					
Test		**1**	**2**	**3**	**4**	**5**	**Mean**	**Least trained for**	**Most trained for**	**Easiest**	**Most difficult**
50m swim	**%**	50.6	23	14	6.2	6.2	1.94 ± 1.21	14.3	0	28.6	0.6
25m tow	**%**	51.7	25.3	11.8	4.5	6.7	1.89 ± 1.19	11.2	0.6	1.3	2.5
400m swim	**%**	46.6	22.5	16.9	7.3	6.7	2.05 ± 1.24	11.8	11.7	4.5	17.2
Jerry-can walk	**%**	6.2	9.6	21.9	33.7	28.7	3.69 ± 1.16	12.4	15.4	1.9	37.6
12km pack march	**%**	2.2	2.8	16.9	37.6	40.4	4.11 ± 0.94	4.3	35.8	0	24.2
Fireman carry	**%**	1.7	2.3	10.7	36.7	48.6	4.28 ± 0.87	5	0	3.9	1.3
1.8m wall	**%**	5.6	5.6	10.7	37.6	40.4	4.02 ± 1.12	11.8*	0*	42.2*	0*
1.8m long jump	**%**	14	12.9	18.5	29.2	25.3	3.39 ± 1.36	11.8*	0*	42.2*	0*
6m rope climb	**%**	17	20.5	33.5	15.9	13.1	2.88 ± 1.25	19.3	0	1.3	8.3
M4 and Glock shoot	**%**	0.6	0	3.9	10.1	86	4.81 ± 0.54	9.9	4.3	7.1	3.2
Coopers run	**%**	5.1	6.7	14	32.6	41.6	3.99 ± 1.13	0	32.1	9.1	5.1

*The survey combined the 1.8m wall and 1.8m long jump when asking questions; hence the results for the 1.8m wall and long jump are the same.

When analysing the perceived relevance of AOS selection tasks the most important number to look at is the mean. The closer the mean is to 5 the higher the relevance of the task; conversely the closer the mean is to 1 the lower the relevance. Table 5.1 shows the M4 and Glock shoot; fireman carry; 12km pack march; 1.8m wall climb; Coopers run; Jerry-can walk; and 1.8m long jump are perceived by AOS members as having moderate to high relevance to AOS duties. Notably, all three water based competencies were perceived to have low relevance to AOS duties.

5.3.6. Failed AOS selection

All candidates who had failed the AOS selection course were sent a separate survey as they did not meet inclusion criteria for the main survey document. Analysis of this data showed that the three areas with the highest failure rate were the physical competency test [PCT] wall/jump (27.3 %), exam (18.2 %) and scenarios (18.2 %). The majority spent 5-12 hours per week training specifically for the AOS selection course for a total of 9-16 weeks. Only 45.5 % were provided with a training programme or advice; with 66.7 % of this advice coming from current AOS members and 33.3 % from a prescribed training programme. A total of 54.5 % felt that their training programme leading up to AOS selection was correct, with 54.5 % perceiving the AOS selection course to be unfair.

5.4. STG specific sample

5.4.1. Training tendencies and behaviours

Of all the STG operators surveyed, 54.3 % took an average of 4 ± 2.8 weeks leave to specifically train for the STG selection course, with 84.2 % of this leave being paid. Figure 5.4 shows the weekly training hours prior to nomination for STG selection course, whilst training specifically for selection and after being accepted into the STG.

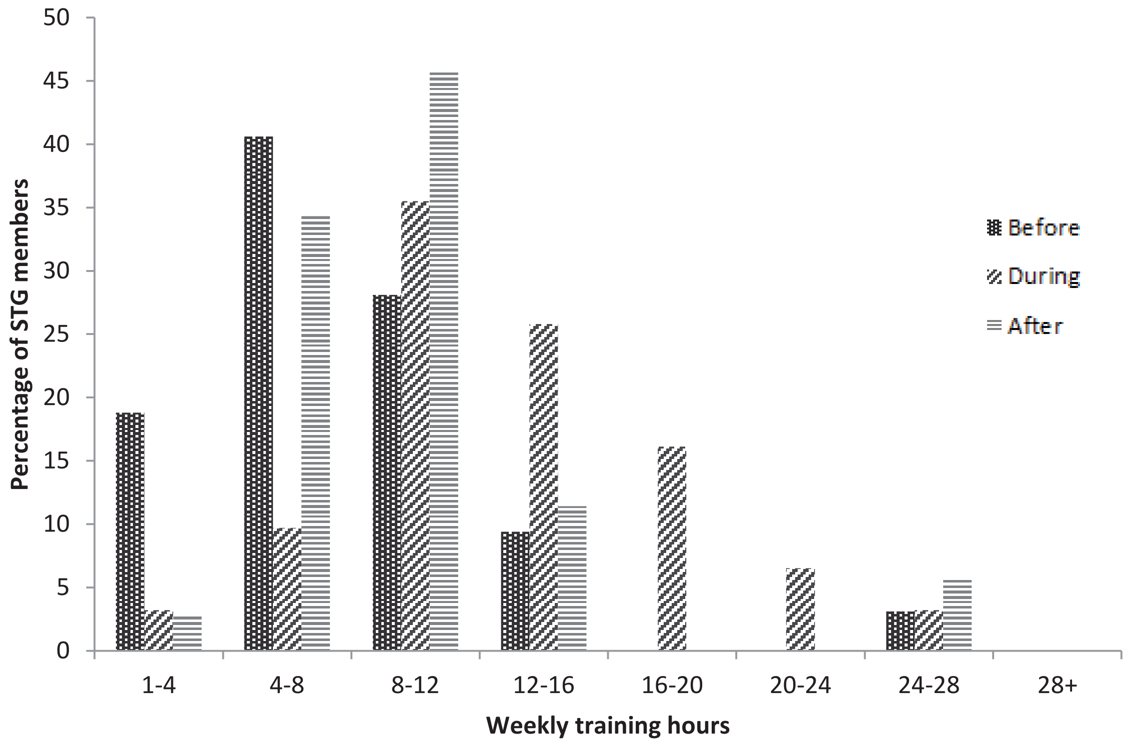

Figure 5.4. Weekly training hours before joining STG, whilst training specifically for STG selection course and after becoming an STG operator.

Of all STG operators, 12.5 % suffered an injury as a result of training for selection. Of these injuries 75 % were to the ankle/calf area with 50 % being a muscle strain. When analysing STG maintenance training, over half (54.3 %) of all operators suffered an injury. Of these, the most frequently injured areas were the calf/ankle (26.9

%), back (23.1 %), and knee (19.2 %); with 65.4 % of all maintenance injuries resulting from muscle strain.

5.4.2. Demands of the STG role

On a day-to-day basis, STG operators perceived their role to be moderately to highly demanding both physically (3.47 ± 0.86) and mentally (3.32 ± 0.68). However, when on deployment the role was perceived to be more demanding physically (4.29 ± 0.80) and mentally (4.41 ± 0.7).

5.4.3. The requirement to perform job specific tasks

STG members felt that the blue role (operating in the open-ocean), ship ladder climb and rappelling were not often performed on the job, see Figure 5.5 below. The frequency of performing a 20km march on deployment was also low, while the completion of a 12km pack march/run, and the use of physical force and firearms are carried out more often. The most often performed tasks on deployment were bush surveillance (4.62) and infiltration (4.38).

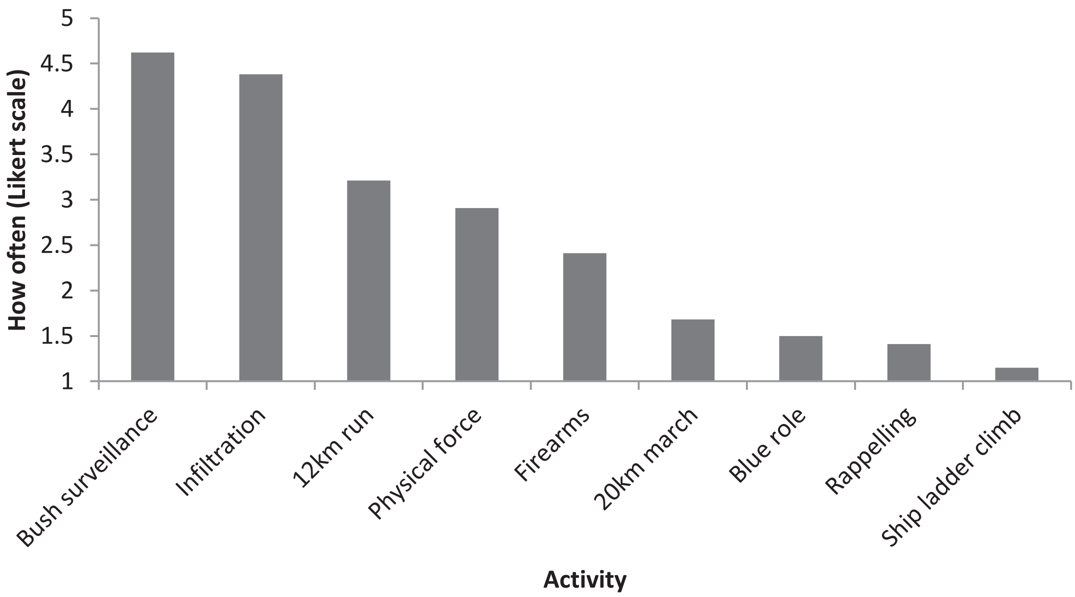

Figure 5.5. How often specific occupational activities have been completed whilst on deployment, one represents not often, five represents very often.

5.4.4. Relevance of selection tests to STG role

Table 5.2 details subjective information about the perceived relevance of STG selection tests to the role of an STG operator, as well as the tests most or least trained for, and the most difficult or easiest tests. When analysing the perceived relevance of the tasks the most important number to look at is the mean. The closer the mean is to 5 the higher the relevance of the task; conversely the closer the mean is to 1 the lower the relevance. As depicted in Figure 5.6, tests scored between 2.33 and 3.66 are perceived to have moderate relevance to job demands; while those scoring > 3.66 are perceived to have high relevance.

5.4.5. ACSM fitness components

A comparison of the perceived relevant physicality of the STG job revealed muscular endurance to be the most important (4.74 ± 0.62), followed by cardiovascular fitness (4.64 ± 0.49), muscular strength (4.47 ± 0.61), flexibility (4.06 ± 1.01), and finally body composition (3.82 ± 1).

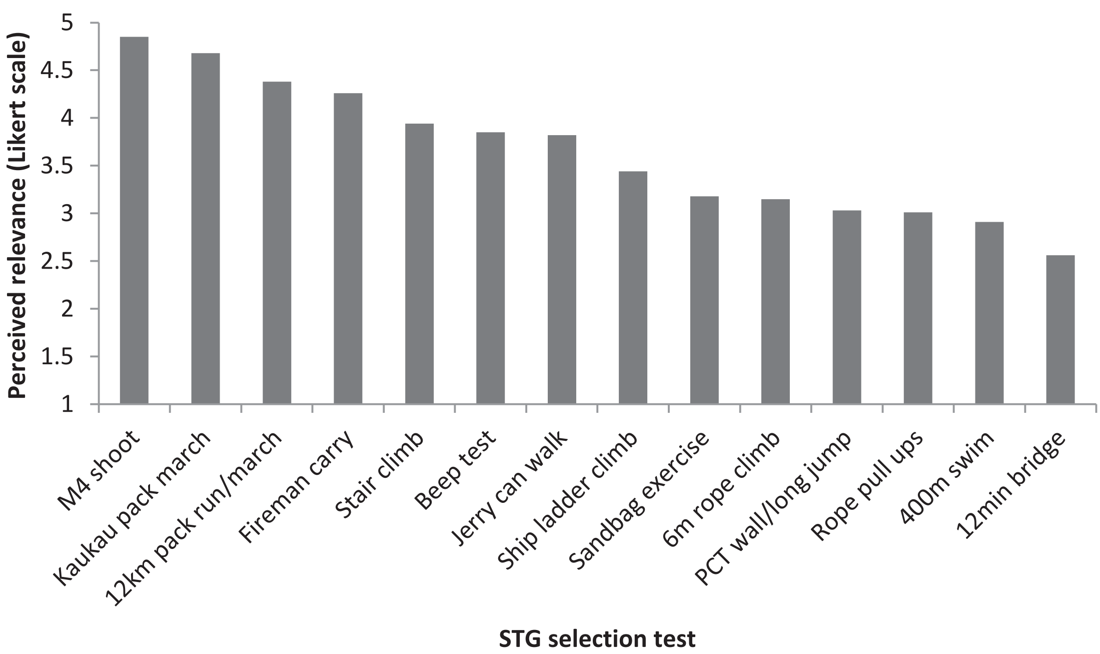

Figure 5.6. Perceived relevance of STG selection tests to the role of an STG operator.

Table 5.2. Perceived relevance of the STG selection tests to the role of an STG operator, the tests most or least trained for and the tests found easiest or most difficult.

		Little		Relevance		High					
Test		**1**	**2**	**3**	**4**	**5**	**Mean**	**Least trained for**	**Most trained for**	**Easiest**	**Most difficult**
Rope pull-ups	%	23.5	8.8	17.6	35.3	14.7	3.01 ± 1.42	10.7	14.8	16.1	9.7
Stair climb	%	2.9	2.9	23.5	38.2	32.4	3.94 ± 0.98	10.7	0	19.4	0
12min bridge	%	38.2	11.8	14.7	26.5	8.8	2.56 ± 1.46	3.6	11.1	0	12.9
Beep test	%	5.9	5.9	11.8	50	26.5	3.85 ± 1.08	3.6	3.7	3.2	6.5
400m swim	%	23.5	8.8	29.4	29.4	8.8	2.91 ± 1.31	21.4	3.7	16.1	6.5
Jerry-can walk	%	5.9	8.8	20.6	26.5	38.2	3.82 ± 1.28	0	14.8	0	25.8
Kaukau pack march	%	0	0	2.9	26.5	70.6	4.68 ± 1.22	0	22.2	0	19.4
M4 shoot	%	0	0	2.9	8.8	88.2	4.85 ± 0.44	14.3	0	19.4	3.2
Ship ladder climb	%	6.3	15.6	25	34.4	18.8	3.44 ± 1.16	10.7	0	3.2	0
12km pack run/march	%	0	8.8	8.8	17.6	64.7	4.38 ± 0.99	0	29.6	0	16.1
Fireman carry	%	2.9	5.9	5.9	32.4	52.9	4.26 ± 1.02	7.1	0	0	0
6m rope climb	%	11.8	14.7	38.2	17.6	17.6	3.15 ± 1.23	0	0	3.2	0
PCT wall/long jump	%	11.8	29.4	20.6	20.6	17.6	3.03 ± 1.31	10.7	0	19.4	0
Sandbag exercise	%	12.1	12.1	36.4	24.2	15.2	3.18 ± 1.21	7.1	0	0	0

When analysing the perceived relevance of STG selection tasks the most important number to look at is the mean. The closer the mean is to 5 the higher the relevance of the task; conversely the closer the mean is to 1 the lower the relevance. Table 5.2 indicates that the three tests with the lowest perceived relevance to the STG role included the 12 minute bridge, 400m swim and rope pull-ups.

6. DISCUSSION

A response rate of 70 % is usually considered optimal to maintain external validity, ensuring the data is representative of the population (Henry & Zivick, 1986; Matthews & Kostelis, 2011; Rubenfeld, 2004). However, as this research involved a small, well-defined population the combined response rate of 63.7 % maintained high external validity of the web-based survey (Portney & Watkins, 2000). Hence, the results can be generalised to the entire AOS and STG population.

Analysis of the survey data, presented a detailed profile of both AOS and STG members for the NZ Police, in addition to providing evidence for Phase Two of the research. The rope pull-up had moderate perceived relevance to job demands, but was coupled with a high failure rate (see pg. 67 for a description and image of the pull-up exercise). The 12 minute bridge test received the lowest perceived relevance of all the selection tests.

6.1. Demographics

No significant difference in the demographic profiles of the AOS and STG indicated that there were no obvious demographic hindrances to an AOS member progressing onto the STG. However, Figure 5.1 identified that both groups are predominately > 38 years of age, especially the STG with 77.2 % of all operators being above that age category. Muscle strength, muscle power and functional mobility have been shown to steadily decrease over the adult age range in healthy populations (Larsson, Grimby, & Karlsson, 1979; Samson et al., 2000). Therefore, the annual fitness assessment is important to ensure each STG member possesses appropriate levels of physical fitness to adequately perform their duties, and that each element of required physical fitness is appropriately tested. The demands of the STG role were identified as being highly physically demanding i.e. requiring high levels of cardiovascular fitness, flexibility and muscular endurance/strength, thus emphasising the importance of the annual fitness assessment.

Due to the majority of STG operators being > 38 years old, it may be suggested that the NZ Police 'market' the STG role to young/new officers as a career option. It was shown that officers gain a better understanding of the STG role once they become AOS members; this improved understanding appears to make tactical operations more appealing. This finding is further highlighted through a recurring theme among subjective feedback, indicating that once in the AOS, a greater understanding of the STG through exposure to STG operators made the position more appealing.

The demographic profile reveals that most AOS members are family men; therefore, having to take leave to train for the AOS selection course could prove to be a deterrent for applicants into the AOS. The danger associated with being in the AOS and STG may also have an impact on consideration of family circumstances. Compared to other lines of employment, police work is considered a particularly stressful occupation, for various reasons including the impact on family life (Burke, 1994; Goodman, 1990). Burke (1994) identified that police officers detailing greater concerns about their health and safety expressed more intention to quit their job because of the impact this may have on family. The danger associated with the AOS and STG roles could have familial reflections. This was shown to be an important consideration for NZ Police hierarchy when addressing recruitment into the AOS and STG. However, 66.5 % of all officers did not take any leave to train for the selection course; so alternatively, it could be a matter of personal fitness level and preparation for those who require leave.

Over half of all AOS members indicated they would not want to move from their current location or residence to join the STG. This is another important area when exploring potential reasons why AOS members may not wish to progress onto the STG. Of the factors associated with moving location, the top five considerations were: family; living costs; housing; lifestyle; and friends. Importantly, family, friends and lifestyle are key areas of support which police officers may be especially aware of when dealing with job demands (Martinussen, Richardsen, & Burke, 2007). In addition to leaving support networks, moving from their current location also adds to the stress of increased living costs, as does finding housing arrangements in the major cities where the STG are situated. Hence, multiple factors are impacting on AOS members decisions not to move location to join the STG. Remaining with support systems, and minimising external sources of stress may buffer the development of emotional exhaustion, fatigue and dissatisfaction for the individual (Martinussen et al., 2007).

A possible outcome of chronic stressors associated with police work is burnout (Burke, 1994; Martinussen et al., 2007). Burnout is a psychological syndrome occurring in response to chronic stress in the work place (Martinussen et al., 2007; Maslach, Schaufeli, & Leiter, 2001). This manifests as emotional exhaustion, fatigue and dissatisfaction in work accomplishments (Martinussen et al., 2007). Importantly, level of education is of relevance when assessing a candidate's suitability to enter and deal with the added stressors of the AOS and STG. Previous research has shown amongst Police employees that higher levels of education are associated with lower psychological symptoms and negative feelings associated with burnout (Burke, 1994). Interestingly, 50.5 % of all AOS and STG members identified as having some form of tertiary education, which may be an important element to possess in order to deal with stresses of increasingly dangerous roles.

Interestingly, 47.4 % of AOS members perceived that participation within the STG would inhibit their career development within the police ranks. This is an internal issue for consideration that is beyond the scope of the research project. However, it is important for the NZ Police to identify whether a role with the STG inhibits progress within the police ranks, and if so, why? This may relate to risk vs. reward: is the increased risk and sacrifice of current lifestyle justified with appropriate reward?

6.2. AOS selection tests

6.2.1. Training tendencies

Of all AOS members who passed selection, the greatest majority of them spent 8-12 hours per week training specifically for the selection course, with only 31.3 % training less than 8 hours. Furthermore, 79.2 % of all successful members spent > 4 weeks training specifically for AOS selection. Of candidates who passed the AOS selection course, 53.2 % were provided with training advice or a training programme for their preparation. There was no significant difference ($P > .05$) in whether they were from a major city (Auckland, Wellington, Christchurch) or a North/South Island minor city and whether or not they received training advice. This confirms that participant location did not significantly influence the training advice received.

Unsuccessful candidates spent similar time training for the selection course. However, only 45.5 % were provided with a training programme or advice; with 66.7 % of this advice coming from current AOS members and 33.3 % from a training programme prescribed by NZ Police physical training instructors. It is widely recognised that physical preparedness is critical amongst military and special operations forces (Carlson & Jaenen, 2012). Training should include a variety of cardiovascular, strength and endurance elements to address the physical demands of job specific tasks assessed in selection procedures (Carlson & Jaenen, 2012). Seeking appropriate training advice from trained personnel may be critical in ensuring physical preparedness for the selection protocol.

6.2.2. Physical competencies

All three of the water-based competencies (50m swim, 25m tow and 400m swim) were perceived to have little relevance to the AOS role. It is important to recognise that although the need to perform certain physical abilities (such as swimming) may be infrequent, they are often critical (Bonneau & Brown, 1995). Hence, the need to perform these tests is currently justified by the need for occupational competency in the water (New Zealand Police., 2011). The 50m swim must be completed in less than 60 seconds, and therefore assesses a candidate's swimming speed. Whereas the 400m swim assesses swimming ability and is a compulsory task to be completed (with no specified time limit). Therefore both tests are relevant as they assess different physical requirements related to swimming. Notably, the 400m swim was perceived as the third hardest test to pass. Poor swimming techniques will likely cause difficulty completing the 400m swim; however, as swimming is an occupational health and safety requirement it should be argued that candidates work on their technique.

The 12km pack march which serves as an assessment of job specific muscular endurance, and the Cooper's (1968) 12 minute run, which provides a cardiovascular assessment, were both perceived to have high relevance to the AOS role. The aforementioned tests were also the most trained for; however, the Cooper's run was not particularly difficult for AOS members. The Cooper's (1968) test involves running a maximal distance in 12 minutes, and is considered a maximal cardiovascular test. The Cooper's run is a well validated measure of cardiorespiratory fitness, and can be used to predict VO_{2max}[1] with the equation ([distance m – 504.9]/44.73) (Cooper, 1968; Grant, Corbett, Amjad, Wilson, & Aitchison, 1995). Importantly, this equation has very strong correlations to VO_{2max} values obtained using graded exercises tests (Burke, 1976; Mccutcheon, Sticha, Giese, & Nagle, 1990; McNaughton, Hall, & Cooley, 1998). Table 6.1 details the minimum distance required for male and female AOS members for set age brackets.

Table 6.1. Required Coopers run distances for NZ Police AOS and corresponding VO_{2max}.

Age	Sex	Required Distance (m)	Corresponding VO_{2max} (ml.kg.min^{-1})
20-25	M	2700	49.07
	F	2500	44.6
26-35	M	2600	46.84
	F	2400	42.37
36-45	M	2500	44.6
	F	2300	40.13
46-50	M	2400	42.37
	F	2200	37.9

M = male; F = female

The fact that the Cooper's run was perceived as not particularly difficult for AOS members could be due to a matter of preparedness, or easy test standards. The VO_{2max} classifications for healthy populations are defined in Table 6.2. It is shown that the minimum required AOS aerobic capacity is classified as good-excellent. Physiological research has identified highest aerobic capacities of 55 ml.kg.min^{-1} for U.S. Army Special Forces (Beckett, Goforth, & Hodgdon, 1989). However, the U.S. Army Special Forces are a full time unit, with a role that is much more physically

[1] VO_{2max} is the maximum rate at which oxygen can be delivered to, and utilised by the muscles during exercise; it is used to assess an individual's aerobic capacity.

demanding than the AOS. Based on the role of the AOS, the current required minimum aerobic capacity (assessed by distance run in Cooper's test) is considered relevant.

Table 6.2. Cardiorespiratory fitness classifications (VO_{2max} [ml.kg.min^{-1}])

Age	Sex	Fair	Good	Excellent	Superior
20-29	M	42-45	46-50	51-55	56+
	F	36-39	40-43	44-49	50+
30-39	M	41-43	44-47	48-53	54+
	F	34-36	37-40	41-50	46+
40-49	M	38-41	42-45	46-52	53+
	F	32-34	35-38	39-44	45+
50-59	M	35-37	38-42	43-49	50+
	F	25-28	29-30	31-34	35+

Adapted from: Heyward, (2010). Advanced fitness assessment and exercise prescription.

The Jerry-can walk is considered the most difficult of all selection tests, yet it is not extensively trained for. This test requires candidates to carry a 17kg Jerry-can across a selected 20km route for a duration of four hours. Candidates must be carrying their own Jerry-can at all times and must equally share in the carrying of an extra Jerry-can, weighted as 5.6kg per member of their team. While the specificity of the Jerry-can task to the AOS role can be questioned, the task is designed to assess each candidate's psychological response to a demanding physical stress, and also to assess team work rather than the act of carrying the Jerry-can itself. As such the task was perceived to have moderate-high relevance to the AOS role. Due to the associated difficulty of the Jerry-can test, and the fact it is not extensively trained for, additional prescriptive training advice for this task may be needed for future AOS selection courses.

6.2.3. Relevance of physical fitness components

Physical fitness is a term which encompasses a variety of components. In order to determine or test an individual's physical fitness, the fitness components relevant to their job/role need to be identified. The highly regarded American College of Sports Medicine [ACSM] (2010) has identified and detailed five fundamental components of physical fitness. The relevance of each of these components was rated by members of the AOS.

Cardiovascular fitness is the ability to deliver oxygen to working muscles in order to sustain physical activity. This had the highest perceived relevance of all physical fitness components (4.33 ± 0.72). This component of physical fitness is adequately assessed in in the selection course with tests including the Cooper's run and 400m swim, and annually with the Cooper's run.

Muscular endurance is the ability of a muscle or muscle group to sustain repeated contractions, or maintain a position for a period of time. This component received the second highest relevance (4.29 ± 0.73), and is also adequately assessed in the selection course with the 12km pack march, Jerry-can walk, 100m fireman carry and 400m swim. However, annually there is no direct assessment.

Muscular strength is the maximal force produced by a muscle or muscle group in order to overcome resistance, and had high perceived relevance (3.9 ± 0.80). While maximum strength is not tested in the AOS selection course per se, measures of operational strength are assessed through the 1.8m wall climb, 1.8m long jump and 6m rope climb. In the British, Canadian and U.S. Army there has been a transition towards task-specific testing for physical fitness (Reilly, 2010). When performing operations in a suburban environment, people may be required to scale walls or jump obstacles, with each requiring a certain level of strength to perform the task (Reilly, 2010). Although the exact level of required strength to perform certain physical tasks pertinent to the AOS role is not known, it can be assumed that the wall climb, long jump and rope climb encompass elements of muscular strength required for completion of similar tasks during AOS deployment.

Body composition is the proportion of fat mass to lean muscle mass, and scored 3.55 ± 1 on the Five-point Likert scale. This physical fitness component is not currently assessed, and it is recommended that this should remain so. If an individual is able to pass the annual fitness assessment they are deemed to have appropriate physical fitness to perform the AOS role regardless of body composition.

Flexibility is the degree of movement that occurs at a joint, as measured by range of motion. Interestingly, this component received a moderate-high score (3.5 ± 0.93). Flexibility is not tested at all; however, it is important to note that 48.8 % of all AOS maintenance injuries are caused by muscle strains. It has been well documented that the incidence of muscle strain can be decreased with increased flexibility (Bradley & Portas, 2007; Dadebo, White, & George, 2004). This may provide rationale to include a selection and annual flexibility assessment. However, a flexibility assessment should be used as a screening tool identifying those at greater risk of injury, rather than a pass/fail component. This would ensure that flexibility is appropriately targeted when training for selection.

6.2.4. Training regime

When asked to rate their current level of fitness from first passing the AOS selection course on a scale of 1-5 with 1 representing less fit, 3 representing the same and 5 representing more fit; on average AOS members scored 2.81 indicating that their fitness levels had slightly decreased from when they first passed selection. Not surprisingly, STG members scored an average of 3.97 signifying they were more fit from first passing AOS selection. Maintaining a higher level of fitness could result in an increased number of AOS members possessing a level of fitness adequate to pass STG selection after they have gained appropriate experience within the AOS. It could also be argued that a more specific AOS annual fitness assessment would maintain a higher level of fitness. The average length of service in the AOS was 8.2 ± 6.5 years. This length of service may be one reason for the decrease in fitness level, with age associated declines in muscle strength, muscle power and functional mobility (Larsson et al., 1979; Samson et al., 2000).

6.2.5. Value of testing protocols

Just over half of all AOS and STG members felt it would be beneficial for the AOS to have a more specific annual fitness assessment. There was a strong trend (P = .058) indicating that members with longer weekly training hours perceived a more specific annual assessment as beneficial, as opposed to those who have lower weekly training hours. Therefore, it may be assumed that individuals with better training tendencies (and most likely higher levels of fitness) would approve of a more specific annual fitness assessment.

A question was asked in regard to the possible idea of improving applicant numbers into the STG by choosing to complete an additional day at the end of the AOS selection course, enabling a more direct career in the STG. Interestingly, 74 % indicated that they would consider completing the additional day, with no significant differences between AOS and STG members. However, the results of this question do not match with the data from the question "prior to selection into AOS did you have any aspiration to move onto STG" of which only 35 % indicated they did have aspiration to progress to STG. The response of this question could be explained by two things:

1. Dissociation from the questions (DePoy & Gitlin, 2011), or

2. With the completion of an additional day being a question based on physicality, candidates may perceive it as easy to complete an additional day as they have already done intensive training in the lead up to AOS selection (i.e. kill two birds with one stone) for which they would broaden their future career options. As such, candidates may perceive the additional day to be an overall easy option (given the alternative which is another period of intensive training further in the future).

Furthermore, the STG required fitness policy states that 'applicants who wish to be considered for selection as an STG operator must be a current member of the NZ Police AOS, or have previous experience on the NZ Police AOS' (New Zealand Police, 2011). Therefore, without a specific STG selection course, a far more rigorous AOS annual fitness assessment must be implemented to ensure that those who completed the additional day are still of adequate fitness level to fulfil the duties of an STG operator, after gaining experience with the AOS.

6.3. STG selection tests

6.3.1. Training tendencies

Over half of all STG operators took leave to train for the STG selection course with the majority of this leave being paid. The fact that 33.5 % of all officers took leave to train for AOS selection, coupled with over half of all STG operators taking paid leave to train for STG selection, could prove to be a deterrent for AOS members progressing into the STG i.e. more annual leave time would need to be devoted to training. This finding indicates why applicants might perceive the additional day at the end of AOS selection to be a desirable option. A supplementary day at the end of AOS selection could improve applicant numbers for the STG. However, as mentioned earlier a more vigorous annual fitness assessment for AOS would also be required.

As shown in Figure 5.4, once accepted into the STG the weekly training hours resume to pre-STG training hours with the majority in the 8-12 hours per week bracket. There was a wide dispersion of weeks spent training specifically for STG selection ranging from 1-24. This preparation period is likely influenced by the candidate's current level of fitness when the decision to progress onto the STG was made, and how much maintenance training was carried out as an AOS member.

A total of 10.7 % of those within the AOS and STG have attended and failed the STG selection course. Of those who had attempted and failed, the majority thought the selection course was fair. Of particular interest, the top three areas of failure were rope pull-ups, the M4 shoot and sustaining an injury with percentages of 17.4 %, 17.4 % and 13 % respectively.

6.3.2. Training injuries

The total number of injuries during the STG selection course is low; however, over half of all STG operators have suffered an injury during maintenance training. To the researcher's knowledge, published data on injury incidence among Police Special Operations groups is non-existent; although there is some data among Army Special Operations groups (Abt et al., 2014; Lynch & Pallis, 2008). Recent research performed on U.S. Army Special Operations Forces found an annual training related injury incidence of 20.8 % among members (Abt et al., 2014). Of the reported injuries, 76 % were musculoskeletal and classified as preventable (Abt et al., 2014). Earlier research on the same group found that of all sustained injuries stemming from physical training, over 40 % were musculoskeletal problems (Lynch & Pallis, 2008). The most commonly injured areas were back/neck, knee, shoulder and ankle (Abt et al., 2014; Lynch & Pallis, 2008). For the STG, the most frequently injured areas were the calf/ankle (26.9

%), back (23.1 %), and knee (19.2 %). Importantly, 65.4 % of all maintenance injuries were caused by muscle strain, and could be deemed preventable.

As mentioned earlier, the incidence of muscle strain could be decreased with increased flexibility (Bradley & Portas, 2007; Dadebo et al., 2004). A muscle possessing greater flexibility has a more compliant muscle-tendon unit (Witvrouw, Mahieu, Danneels, & McNair, 2004). Greater compliance leads to better ability of the tendon to absorb energy during movements, thus lowering the injury risk in the tendon and muscle structures (Witvrouw et al., 2004). Importantly, research has shown that a regular stretching routine can significantly improve muscle-tendon compliance (Kubo, Kanehisa, & Fukunaga, 2002; Kubo, Kanehisa, Kawakami, & Fukunaga, 2001; Witvrouw et al., 2004). Screening assessments test fundamental movements including flexibility, stability and balance; and have been shown to identify risk factors for injury (Kiesel, Plisky, & Voight, 2007; Minick et al., 2010). Hence, flexibility screening to determine muscle-tendon compliance could be used to determine those at greater risk of injury. However, it must be noted that our research did not explore how various injuries developed (e.g. sprained ankles, lower back injury or acutely/chronically excessive loading per se on muscles and/or joints). Therefore, the role of inflexibility on and stretching on injury and injury prevention remains unclear, especially in the context of physically demanding occupations.

6.3.3. Physical competencies

6.3.3a. 12 minute bridge

The three tests with the lowest perceived relevance to the STG role included the 12 minute bridge, 400m swim and rope pull-ups. The 12 minute bridge test is used as an assessment of core stability, by testing core endurance. The test involves cycling through three different bridge positions, each held for 30 seconds, for a total duration of

12 minutes. Core stability has been recognised as extremely important in physical performance, enhancing ability to perform activities of daily living [ADL], and to reduce injury during ADL, sporting activities and during periods of prolonged heavy physical work (Borghuis, Hof, & Lemmink, 2008). While the specificity of the bridge test to the STG role can be questioned, the aspect of physical fitness it is testing cannot be overlooked. The core refers to the trunk and pelvic [lumbopelvic] section of the body (McGill, 2001). The lumbopelvic section consists of various structures to provide a foundation allowing for movement, support and protection (Panjabi, 1992). Two fundamental components to core stability include muscular endurance[2] and muscular strength[3] (ACSM, 2010), with core endurance perceived as more important for injury prevention (Barr, Griggs, & Cadby, 2005; McGill, 2001; McGill, Grenier, Kavcic, & Cholewicki, 2003; Willardson, 2007).

As identified in the survey, the STG are often required to perform physical activity carrying heavy loads for prolonged durations. In order to maintain the spine in neutral alignment during load carriage the core musculature must increase muscle activity to overcome the external resistance (Borghuis et al., 2008; Jones & Knapik, 1999). Hence, a certain level of core endurance is required to perform load carriage activities without predisposing the trunk to injury (Jones & Knapik, 1999; McGill et al., 2003). The most commonly used assessment of core endurance is a sit-up or trunk curl test (ACSM, 2010; Cuddy, Slivka, Hailes, & Ruby, 2011); however, these tests only give an indication of anterior and side core muscular endurance (Burden & Redmond, 2013; Escamilla et al., 2006). The STG 12 minute bridge assesses all core stabilisers

[2] Muscular endurance is the ability of a muscle or muscle group to sustain repeated contractions, or maintain a position for a period of time.
[3] Muscular strength is the maximal force produced by a muscle or muscle group in order to overcome resistance.

(anterior, side and posterior) to ensure an appropriate level of core stability to prevent injury to the trunk. However, the 12 minute duration could lead to fatigue of the core stabilisers, potentially predisposing the spine to injury (Barnes, 1980; Kumar, Pah, & Bradley, 2003; Yoshitake, Ue, Miyazaki, & Moritani, 2001). To our knowledge, there is no existing research examining muscle fatigue during a rotational bridge test.

6.3.3b. 400m swim

Similar to the AOS selection test, STG operators also perceived the 400m swim to have the second lowest relevance to their role. The use of a 400m swim is currently justified by the need for occupational competency in the water (New Zealand Police., 2011). Although, the specificity of the test does not mimic the movement patterns of operational water based tasks. When the STG operator is performing open water operations, they are required to swim on their backs with the aid of fins. It could be proposed that a test requiring candidates to fin on their backs over a set distance in open water would be the most specific test. However, too many uncontrolled variables such as water temperature, tides, current, wind, swell and weather make this unsuitable due to poor retest reliability. For the aforementioned reasons, swim testing needs to be performed in a controlled environment. The typical variation for elite swimmers undertaking a 400m swimming performance test in a pool is reported as low (0.8 % - 1.4 %) (Pyne, Trewin, & Hopkins, 2004; Stewart & Hopkins, 2000).

The ability to swim well is hugely influenced by both fitness and technique (Anderson, Hopkins, Roberts, & Pyne, 2008). Hence, it is assumed that individuals with faster 400m swim times possess either better fitness or technique, or a combination of both (Knechtle, Baumann, Knechtle, & Rosemann, 2010), likely enhancing ability to swim in the open ocean. As an assessment to evaluate each candidate’s water competency, which is required for operational tasks, the 400m swim test serves its purpose; what is lost in terms of validity is compensated with reliability. One possible suggestion to improve validity of testing could be the use of a swimming test performed on their back with fins, in a swimming pool. However, to our knowledge no data exists addressing the test-retest reliability of finning.

6.3.3c. Rope pull-up

The rope pull-up had moderate perceived relevance to the STG role, however, muscular strength is perceived to have high relevance to operational tasks. The pull-up is widely used as a field based assessment of upper body muscular strength amongst many uniformed services (Vanderburgh & Flanagan, 2000; Williams, Rayson, & Jones, 1999). The STG utilise a modified pull-up performed on two lengths of rope with knotted ends. This test is purported to mimic operational climbing tasks such as climbing a rope, or climbing a narrow ship's ladder (caving ladder). However, discussions with current STG operators, NZ Police physical training instructors, and members of the NZ Police hierarchy have identified that when climbing ropes, and performing narrow ladder ascents (with proper technique), the legs are the primary muscles engaged in the movement; as opposed to the arms as suggested in the policy. This is a possible explanation for the low perceived relevance obtained from the survey.

To the researcher's knowledge, only two papers (Ricci, Figura, Felici, & Marchetti, 1988; Youdas et al., 2010) have been published assessing the effect of grip width and orientation on muscle activity during a pull-up activity. There is also no published research investigating the level of muscle activity experienced during operational climbing tasks. Hence, it is difficult to determine the similarity of the rope pull-up to an operational climbing task. It is acknowledged, however, that a certain degree of upper body muscular strength is required by STG members to perform operational duties; including, but not limited to climbing tasks.

6.3.3d. Stair climb

The most often performed operational tasks were also perceived to be the most relevant, including the M4 shoot, Kaukau pack march and 12km pack run; and therefore are deemed as valid tests. Importantly, the stair climb and beep test, which are used as part of the annual fitness assessment, were also seen as relevant to the STG role. The stair climb is used as a lower body muscular endurance/anaerobic capacity test. The test involves ascending six flights of stairs (standardised dimensions), with 20kg of tactical kit in a maximum time of 33 seconds.

Deployments in suburban areas usually require short bursts of high intensity activity, with primary reliance on anaerobic energy systems. Anaerobic energy production is the main contributor to ATP production in maximal exercise lasting less than 75 seconds (Gastin, 2001). The primary metabolic pathway involved in ATP production for short duration (< 10 seconds), high intensity exercise, is phosphocreatine [PCr] (Buchheit, 2012; Gaitanos, Williams, Boobis, & Brooks, 1993; Girard, Mendez-Villanueva, & Bishop, 2011; Powers & Howley, 2009; Tomlin & Wenger, 2001). In conjunction with PCr energy production, anaerobic glycolysis supplies approximately 40 % of the ATP required during sprint activities (Gaitanos et al., 1993). To our knowledge there is no current research examining the energy requirements of the stair climb test. However, the timeframe, and maximal required effort liken the test to a Wingate anaerobic energy assessment. Due to the duration and maximal effort of the stair climb test, it is postulated that the test is specific to potential tasks a STG operator may face. However, the exact anaerobic energy requirements during deployment are unknown. Hence, the required completion time of 33 seconds or less remains unjustified. Further research is needed to determine energy requirements, although direct measurement would be difficult due to safety concerns for researchers and STG operators.

6.3.3e. Beep test

Many exercise physiologists consider VO_{2max} to be the most valid assessment of cardio-respiratory fitness (Heyward, 2010; Kaminsky & ACSM, 2014; Levine, 2008). Due to the high aerobic requirement amongst most uniformed services, aerobic assessments are commonly used (Levine, 2008; Lindstedt & Conley, 2001). There are various laboratory and 'field based' aerobic fitness assessments, with many used to predict VO_{2max}. Two of the more common 'field based' assessments include the Cooper's 12 minute run and the beep test (Cooper, 1977; Leger, Mercier, Gadoury, & Lambert, 1988; Ramsbottom, Brewer, & Williams, 1988).

A certain degree of aerobic fitness is required by members of the STG for performance in prolonged duration exercise, and recovery from repeated high-intensity activity. Higher levels of VO_{2max} are associated with greater cardiac output, capillarisation, mitochondrial density and myoglobin content; resulting in a greater ability to transport O_2 to, and utilise within the muscle (da Silva, Guglielmo, & Bishop, 2010; Dupont, Millet, Guinhouya, & Berthoin, 2005; McKay, Paterson, & Kowalchuk, 2009). Greater aerobic capacity also enhances levels of excess post-exercise oxygen consumption, improving the speed in which PCr is restored to resting levels, and also improving lactate metabolism (Billat, Sirvent, Py, Koralsztein, & Mercier, 2003; Tomlin & Wenger, 2001). Furthermore, increased VO_{2max} results in faster O_2 uptake kinetics allowing a larger contribution of aerobic energy production at a given intensity, thus decreasing the amount of lactate production from anaerobic glycolysis (Billat et al., 2003; Dupont et al., 2005).

The beep test is a well validated measure of cardio-respiratory fitness consisting of a continuous 20m shuttle, with increasing speed levels (Ramsbottom et al., 1988). The STG minimum requirement of level 11 corresponds to a VO_{2max} of 50.3 $ml.kg.min^{-1}$ (Leger et al., 1988; Ramsbottom et al., 1988). Pryor et al. (2012) identified an average VO_{2max} of 45.2 ± 6.1 $ml.kg.min^{-1}$ amongst members of a Suburban Special Weapons and Tactics Team [SWAT]. The authors agree that a high level of cardiovascular fitness is required due to the high physical and physiological stress experienced during SWAT operations (Pryor et al., 2012). However, the VO_{2max} observed in this study is arguably inadequate as it only places them in the 60th percentile compared with the general population (Pryor et al., 2012). Similarly, the Australian Special Forces require a beep test level 10.1, corresponding to a VO_{2max} of 47.1 $ml.kg.min^{-1}$ (Australia Defence Force, 2014). In comparison, previous research has reported highest VO_{2max} values of 58.5, 57.7 and 55 $ml.kg.min^{-1}$ amongst British parachutists, U.S. Navy SEALs and U.S. Special Operations Services, respectively. Based on the role of the STG and requirements of other armed services, the required beep test level 11 is suitable to ensure members can adequately perform operational activities.

6.3.4. Frequency of performing operational tasks

The demand to perform certain operational tasks becomes important when identifying areas of testing which may need to be investigated further. Open water roles, rappelling and climbing a ship's ladder were indicated as tasks not often performed on deployment, and may explain the low perceived relevance of tests used to assess these operational tasks. On the other hand, bush surveillance and infiltration were the most performed operational tasks. As such, the M4 shoot and pack marching were perceived as the highest relevant tests to the occupational role.

6.3.5. Relevance of physical fitness components

In order to determine or test an individual's physical fitness, the physical fitness components relevant to their job/role need to be identified. The relevance of the five fundamental fitness components were rated by members of the STG.

Muscular endurance had the highest perceived relevance to the STG role and is adequately assessed in selection with pack marching, 12 minute bridge test, stair climb, 400m swim, beep test, Jerry-can walk and 100m fireman carry. This component is also assessed annually with the 12 minute bridge test, stair climb, 400m swim, and beep test.

Cardiovascular fitness also received high relevance to the STG role and is adequately assessed at selection, and annually with the beep test and 400m swim.

Muscular strength also had high perceived relevance. However, the only assessment of muscular strength is with the rope pull-ups. As muscular strength has high relevance to job demands there is evidence to suggest a more appropriate assessment of upper and lower body strength be incorporated into the STG selection assessment and annual fitness assessment.

Flexibility was also perceived to be of relatively high importance to the STG role, most probably due to injury prevention reasons. While this component is not tested at all, it could be beneficial to add a flexibility assessment for screening purposes. This may help identify those at heightened risk of muscle strain before injury occurs.

Finally, **Body composition** received the lowest perceived relevance of all fitness components. If STG operators are physically capable of performing their role, as assessed in the annual fitness assessment, then body composition should have no bearing on position within the STG.

6.3.6. Value of testing

All STG operators feel that the annual fitness assessment is beneficial, with 76.5 % believing that the current assessment is an adequate level of fitness for deployment. However, 20.6 % of STG operators felt that at the time of completing the survey they would not be able to pass the annual fitness assessment. Potential reasons were not explored; but current injury could have been a likely barrier.

6.4. Strengths and limitations

One of the main limitations of survey research is that responses consist of self-reported information which may not always be correct (DePoy & Gitlin, 2011). Typically, a previously validated survey tool will be utilised to ensure that survey content is justified. However, as this research was specific to the fitness requirements of the NZ Police AOS and STG, a unique questionnaire had to be designed. A series of methodological processes were employed to ensure validity of the survey tool was maximised. Previous surveys used among uniformed services helped to inform the types of questions to be included. Furthermore, content validity of the survey was maintained by development of the questionnaire with guidance from a three person supervisory team, and expert knowledge from NZ Police hierarchy. Finally, the survey was also pre-tested by members of the police hierarchy to ensure the questions were clear, concise and that the format was easy to follow.

A second limitation of Phase One of the research was the length of the survey (DePoy & Gitlin, 2011). For STG members the questionnaire was estimated to take 30 minutes to complete. Due to the length of time, it is possible that some respondents may have rushed through the document and not paid complete attention to all questions (DePoy & Gitlin, 2011). However, as the research was of particular importance to those participating, it was assumed that all questions were answered to the best of their ability. Furthermore, the population was small and well-defined, with the high response rate ensuring that external validity of the questionnaire was upheld.

7. CONCLUSION

A high response rate for the survey means that results can be generalised to the entire AOS and STG population. The survey provided a comprehensive overview of the AOS and STG demographic profile, reasons why individuals participated in selection tests and how prepared they were for the tests. In addition, areas of testing susceptible to candidate failure, and the relevance of tests utilised were also identified. There were no significant differences in the demographic profiles of the AOS and STG. However, both groups are an aging population. Due to age associated declines in strength, power and functional mobility it is important to ensure that each AOS and STG member possesses appropriate levels of physical fitness to adequately perform their duties. It is important to emphasize that candidates preparing for AOS and STG selection courses seek appropriate training advice from competent personnel. It is recognised that physical preparedness is critical amongst military and special operations forces (Carlson & Jaenen, 2012). Hence, training advice may be crucial in ensuring physical preparedness for the selection protocol.

During selection, the AOS adequately assess the most relevant fitness parameters of cardiovascular fitness, muscular endurance and operational muscular strength. Operational fitness is annually assessed with the standard NZ Police physical competency test, with greater competency required by AOS members in comparison to general police. Furthermore, the perceived most relevant cardiovascular fitness is also adequately assessed annually. From analysis of the survey data, it is concluded that the physical components of the AOS selection protocol, are currently relevant to the AOS role. Components with low perceived relevance, such as the water based competencies, can be appropriately justified.

The high injury rate amongst STG members whilst performing maintenance training is similar to special operational forces elsewhere. Because the majority of these injuries could be deemed preventable it is suggested that a screening assessment be used for current STG members. A trained professional could then prescribe appropriate training to reduce these risk factors.

The STG role is identified as being highly physically demanding. Hence, annual physical fitness testing needs to ensure that members are appropriately tested across all relevant aspects of physical fitness including: muscular endurance; cardiovascular fitness; and muscular strength. As with the AOS, the current use of a 400m swim in the STG annual fitness assessment can be appropriately justified. The 12-minute rotational bridge was perceived to have the lowest relevance to the STG role. While the specificity of this test may be questioned, the aspect of core stability that it assesses is very important to injury prevention during a variety of tasks, including often performed load carriage tasks. However, it is unclear whether the length of the test is safe to perform, warranting further research. Similarly, the rope pull-up received low perceived relevance amongst STG members and needs further investigation to determine whether the test mimics the operational tasks it is purported to. It is important to note that low perceived relevance was the primary factor (but not the definitive factor) when deciding on physical assessments that require further physiological assessment. This is because physical assessments must be indicative of critical job duties and justified as necessities of job duties, behaviours or outcomes when physical fitness policies are utilised to determine an individual's ability to perform their job duties (Hodgdon & Jackson, 2000). Hence, assessments that are perceived as having low relevance to the role must be further investigated to identify whether they are in fact relevant in relation to necessities of job duties.

All other physical competencies performed during the STG initial and annual fitness assessment can currently be justified as relevant to operational tasks. However, although the stair climb test is deemed relevant to the role, future research may need to be performed to identify the exact energy requirements of an STG operator; and whether the required completion time for the stair climb simulates these requirements. Based on Phase One findings, Phase Two of this project will consist of physiological assessments of the rope pull-up and 12-minute bridge test. As detailed in the proceeding sections, the researchers seek to determine whether the rope pull-up test is appropriately justified to mimic operational climbing tasks; and to establish whether the 12-minute bridge test is a suitable test to assess core stability, and if the duration of the test is likely to cause fatigue related injury.

Phase Two: Analysis of rope pull-up and twelve minute rotational bridge

8. INTRODUCTION

Analysis of the Phase One survey data provided evidence to perform a comprehensive assessment of the rope pull-up and 12 minute bridge tests in Phase Two of this project. Concerning the rope pull-up, the survey revealed this test had moderate perceived relevance to job demands, coupled with 17.5 % of candidates who attempted and failed STG selection failing this test. Survey findings relating to the 12 minute bridge showed the test had the lowest perceived relevance of all the selection tests. From the survey results, two major questions were posed.

1) Is the rope pull-up a suitable assessment tool to assess operational climbing tasks?
2) Is the 12 minute bridge test a suitable assessment of core endurance; and if so, is the duration likely to cause injury?

It was hypothesised that the rope pull-up would not simulate required muscle activity during climbing tasks due to biomechanical differences between the rope pull-up and the climbing activities. Regarding the 12 minute bridge test, we expected to confirm the use of a rotation adequately engages all relevant core musculature involved with core stability; however, the duration of 12 minutes was hypothesised to lead to significant fatigue of the core stabilisers.

A sample of current STG operators (who also completed the survey in Phase One) volunteered to participate in the physiological assessments of the rope pull-up and

12 minute bridge test. Surface electromyography [EMG] can be used to examine the aforementioned tests from the STG physical fitness policy. Skeletal muscle serves to provide force generation for movement, with the force produced by a muscle being hugely dependant on the intensity of electrical activity. Hence, changes in muscle fibre recruitment can be detected through changes in EMG signal (Adrian & Bronk, 1929; Talebinejad, Chan, Miri, & Dansereau, 2009). The analysis of EMG signal data provides information about the degree of muscle activity associated with a specific activity, or the amount of fatigue experienced in a muscle (Hatton, Dixon, Martin, & Rome, 2009; Hibbs, Thompson, French, Hodgson, & Spears, 2011).

For the rope pull-up we measured the peak electrical activity of specific muscles involved with the movement. This was then compared to the peak electrical activity of major muscles involved in operational tasks which the test is purported to mimic; including a rope climb and ships ladder climb. Secondary to this, we sought to determine whether rope pull-up ability was influenced by anthropometric variables. For the 12 minute bridge we sought to identify the level of muscle activity involved throughout the test, in addition to the level of muscle fatigue experienced over the duration of the test. To do this a different method of analysis was used to identify the average level of muscle action, and the firing frequency of action potentials. Electromyography provides one means to objectively assess selection tasks, but is not the only relevant objective assessment that may be used.

9. LITERATURE REVIEW

9.1. Electromyographic analysis during pull-up exercises

The pull-up is an exercise widely used as a field based assessment of upper body muscular strength amongst many uniformed services (Figure 9.1a & 9.1b) (Vanderburgh & Flanagan, 2000; Williams et al., 1999). The concentric phase of the exercise requires an individual to grip an overhead bar, utilising muscles including the muscles identified in Figure 9.2a and 9.2b to overcome body mass resistance elevating the body to a desired height, typically judged by the chin being over the bar; the individual then eccentrically lowers their body to the start position (Youdas et al., 2010).

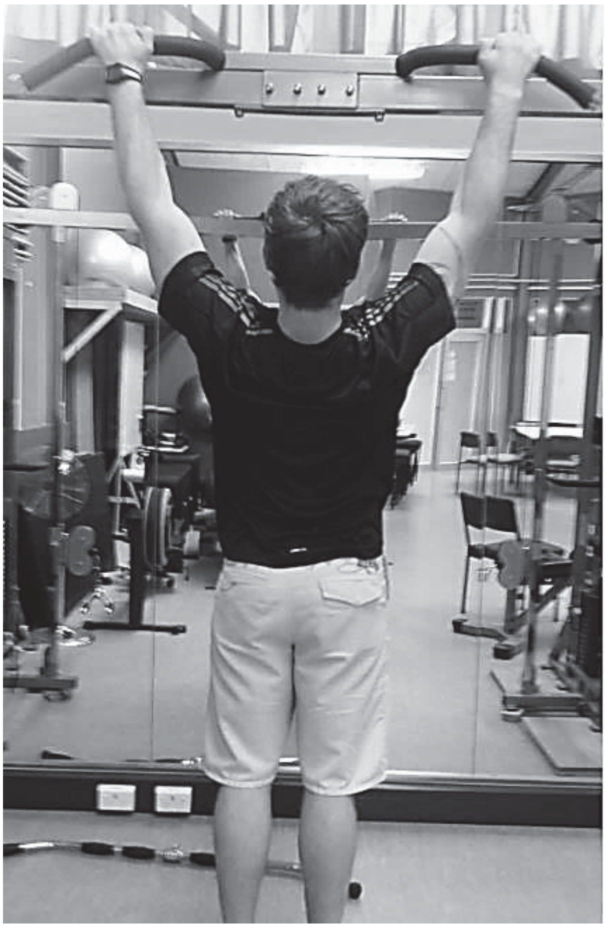

Figure 9.1a. Example of the bottom position in a pull-up exercise.

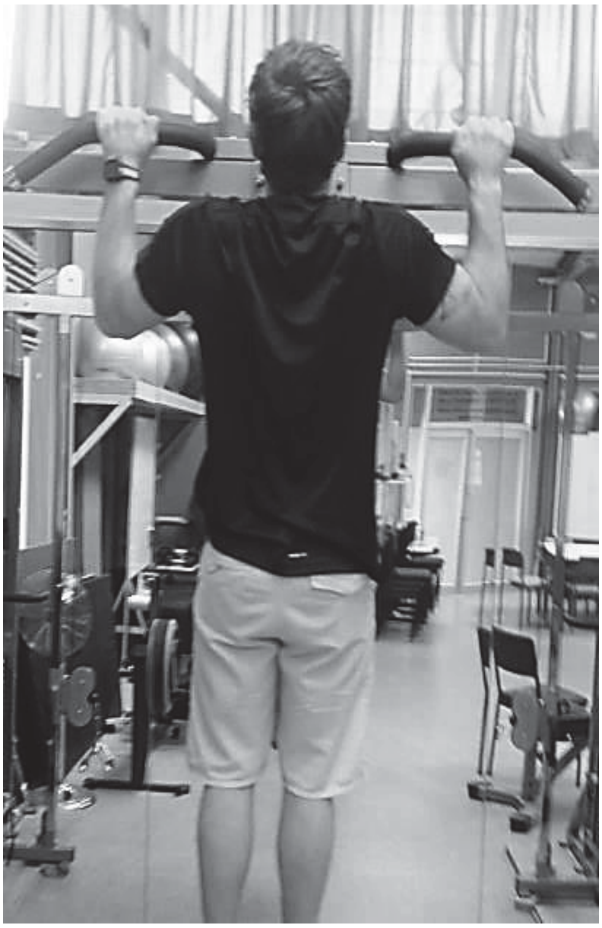

Figure 9.1b. Example of the top position in a pull-up exercise.

The pull-up can involve many different grip widths and orientations, with each placing different biomechanical demands on the associated musculature. The STG utilise a pull-up exercise performed on a rope with two knotted ends separated 15cm apart. This exercise is supposed to assess the strength of muscles required during operational climbing tasks such as climbing a rope or climbing a narrow ships ladder (caving ladder). Climbing a ships ladder has been recognised as extremely dangerous in the maritime industry, averaging six deaths per year during pilot ladder transfers (Weigall, 2006). A certain degree of muscular strength is required to overcome the muscular demands associated with climbing a ships ladder (Weigall, 2006). Therefore, it is important that a test utilised to simulate climbing a ships ladder is reflective of the muscle activity required during the climbing task, minimising the risk of potential falls.

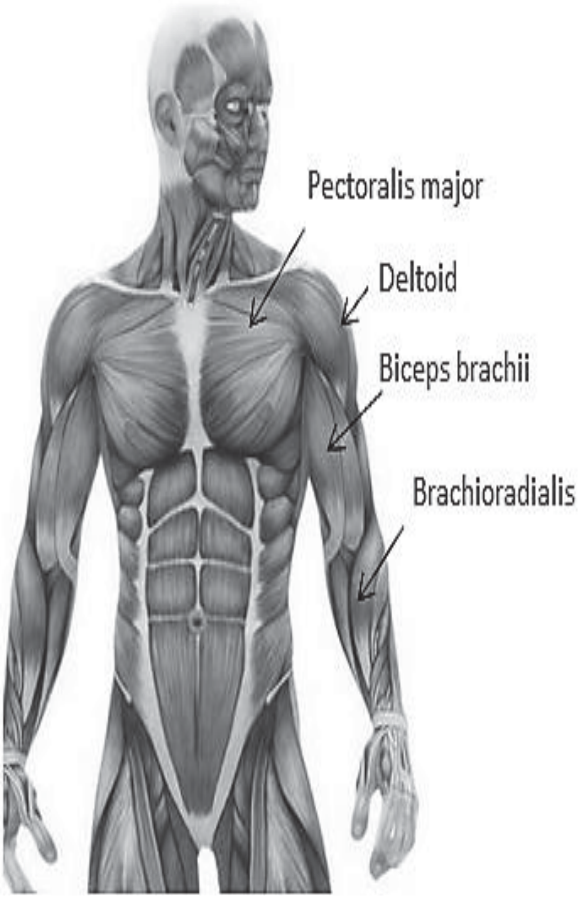

Figure 9.2a. Anterior view of muscles to be assessed in upper body tasks. Marieb. (2013). Essentials of human anatomy and physiology [image]. Retrieved from: http://web.uaccb.edu

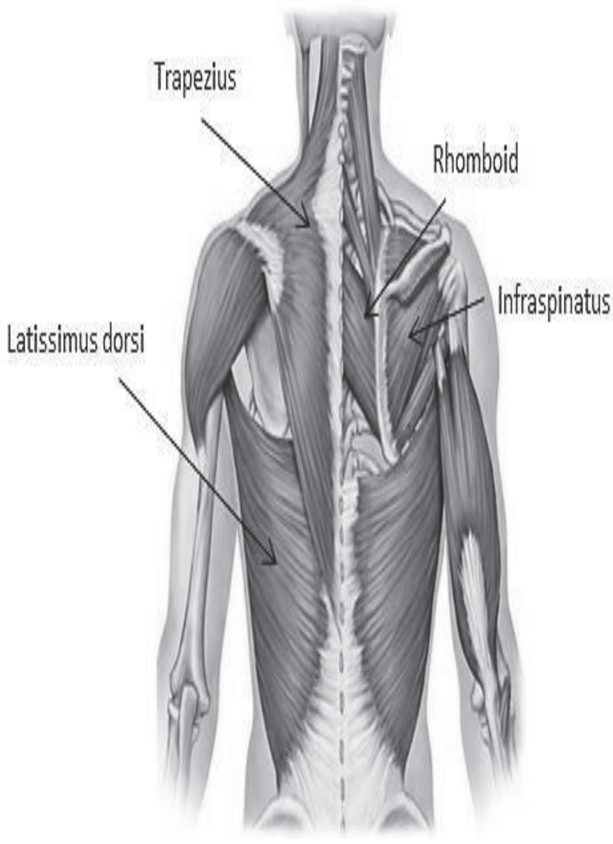

Figure 9.2b. Posterior view of muscles to be assessed in upper body tasks. Marieb. (2013). Essentials of human anatomy and physiology [image]. Retrieved from: http://web.uaccb.edu

A literature search was performed on the 1/8/2014 utilising the SPORTDiscus, Web of Knowledge, PubMed and Google Scholar databases searching key terms ‘pull-up’ or ‘chin up’ combined with EMG or electromyography or ‘muscle activ*’. Additionally, the articles retrieved were used for a related articles search. Two articles were retrieved which utilised EMG to assess muscle activation during pull-up exercises. As such, the search was extended to include open kinetic chain ‘pull-down’ exercises which are purported to mimic the movement associated with the pull-up, resulting in a further four papers relative to the area of research being retrieved. Although the muscle activity associated with varying limb orientations has been widely assessed in lower body squat exercises (Caterisano et al., 2002; Marcora & Miller, 2000; McCaw & Melrose, 1999) and upper body bench press exercises (Lehman, 2005; Santana, Vera-Garcia, & McGill, 2007) Youdas et al. (2010) recognised the lack of evidence surrounding muscle activation during the pull-up, despite familiarity with the exercise amongst fitness professionals.

Movement accompanying the pull-up exercise originates from the elbow and shoulder joints. During the rope pull-up, the upward phase is caused by synchronised flexion of the elbow, extension of the shoulder, and adduction of the scapula. The main muscles utilised for these particular movements include: brachioradialis and biceps brachii for elbow flexion; latissimus dorsi for shoulder extension; and middle and lower trapezius for scapula adduction (Floyd, 2012; Ronai & Scibek, 2014; Youdas et al., 2010). Other muscles previously identified as important in the pull-up movement include the brachialis for elbow flexion; lower fibres of the pectoralis major, and posterior deltoid for shoulder extension; and rhomboids for scapula adduction (Lusk, Hale, & Russell, 2010; Ricci et al., 1988; Ronai & Scibek, 2014; Youdas et al., 2010).

Importantly, the infraspinatus is crucial during upper extremity movement to stabilise the glenohumeral joint (Labriola, Lee, Debski, & McMahon, 2005).

In order for muscle contraction to occur, an electrical impulse [action potential] must travel to a muscle, stimulating contraction (Towler, Kaufman, & Brodsky, 2004). At the point where the electrical impulse reaches the muscle, it branches out to innervate multiple muscle fibres (Broman, De Luca, & Mambrito, 1985; Plowman & Smith, 2014). Each action potential elicits a contraction at each muscle fibre it innervates, resulting in movement (Gordon, Thomas, Munson, & Stein, 2004). Importantly, force production is regulated by the total amount of muscle fibres that are stimulated by an action potential, and the firing rate of the action potentials (Talebinejad et al., 2009). With increased force level there is increased muscle fibre recruitment, detected as a rise in EMG signal (Adrian & Bronk, 1929; Talebinejad et al., 2009). Therefore, the force which a muscle produces is hugely dependant on the intensity of electrical activity.

To date only two papers (Ricci et al., 1988; Youdas et al., 2010) appear to have been published assessing the effect of grip width and orientation on muscle activity during a pull-up activity. Ricci et al. (1988) analysed the muscle activation of the latissimus dorsi, infraspinatus, teres major, upper pectoralis major, lower pectoralis major, middle deltoid, biceps brachii and triceps with the use of surface EMG during shoulder-width supinated and shoulder-width pronated movements. The concentric movement was broken into three phases, initial, middle and final; it was reported that during the initial stage the teres major, upper pectoralis, biceps brachii, infrspinatus and latissimus dorsi were active (Ricci et al., 1988). During the middle phase activity of the latissimus dorsi and infraspinatus was "pronounced" and remained so during the final phase, with reduced activation of the other five muscles (Ricci et al., 1988). It was also noted that activation of the muscles was comparable irrespective of hand orientation. However, this study only measured four participants, and muscle activity was not normalised to a percentage of maximal voluntary isometric contraction [MVIC]. Expressing EMG data as a percentage of MVIC is paramount to normalise muscle activation across all participants, allowing for the calculation of peak EMG (Youdas et al., 2010).

Youdas et al. (2010) sought to identify the relative activation of associated musculature during the pull-up with surface EMG analysis performed on 21 strength trained participants. The lower trapezius, latissimus dorsi, infraspinatus, erector spinae, pectoralis major, external oblique and biceps brachii were assessed during a pull-up (pronated grip, shoulder-width), chin-up (supinated grip, shoulder-width) and a rotational pull-up (combines the pull-up and chin-up) (Youdas et al., 2010). Muscle activity was reported as a percentage of MVIC obtained through manual muscle testing techniques (Table 9.1). The study demonstrated a significantly greater activation of the lower trapezius during the concentric phase of the pull-up; while the chin-up involved significantly greater activation of the pectoralis major and biceps brachii (Youdas et al., 2010). Of note, peak activation of the measured muscles occurred during the concentric phase of the pull-up movement (Youdas et al., 2010).

Similar planes of movement between pull-up and lat pull-down[4] exercises suggest that prime movers involved in the exercises are comparable. To determine the effect of differing hand grip orientation, and width, on muscle activation Lusk, Hale and Russell (2010) compared normalised EMG data of the latissimus dorsi, biceps brachii and middle trapezius muscles during a lat pull-down exercise at 70 % of 1RM using

[4] Lat pull-down is the commonly accepted abbreviation for the latissimus dorsi pull-down resistance exercise.

narrow supinated, narrow pronated, wide supinated [WS] and wide pronated [WP] grips. In contrast to Youdas et al. the results identified significantly greater activation of

Table 9.1. Muscle activation presented as %MVIC during pull up, chin up and rotational pull up exercises.

Muscle	Pull up (%)	Chin up (%)	Rotational (%)
Lower trapezius	56 ± 21*	45 ± 22	NV
LD	NV	117 ± 46	130 ± 53
IS	79 ± 56	NV	71 ± 52
ES	39 ± 31	41 ± 24	NV
Pectoralis major	44 ± 27	57 ± 36*	NV
External oblique	31 ± 24	35 ± 24	NV
BB	78 ± 32	96 ± 34*	NV

NV = no value provided in written format; * = significant difference; LD = latissimus dorsi; IS = infraspinatus; ES = erector spinae; BB = biceps brachii. *Modified from:* Youdas et al. (2010). Surface electromyographic activation patterns and elbow joint motion during a pull-up, chin-up, or perfect-pullup (Tm) rotational exercise. *Journal of Strength and Conditioning Research.*

the latissimus dorsi expressed as a percentage of MVIC (67 ± 14 % WP vs. 62 ± 13 % WS) as an effect of forearm orientation but not width; furthermore there were no significant correlations observed between grip width and orientation, and the biceps brachii muscle (Lusk et al., 2010). Increased latissimus dorsi activation has been observed during pronated wide grip pulling anterior to the head in comparison to pronated wide grip pulling posterior to the head, supinated wide grip and close [neutral] grip (Signorile, Zink, & Szwed, 2002); however, no differences in latissimus dorsi and biceps brachii activation between pronated and supinated grips have also been reported (Lehman, Buchan, Lundy, Myers, & Nalborczyk, 2004). This latter finding may be due to the participants not eliciting a maximal muscle activation output because of a low resistance of 10-12RM being utilised.

The ability to provide propulsion and avoid falling whilst climbing requires a certain degree of strength pertinent to the climbing task (Koukoubis, Cooper, Glisson, Seaber, & Feagin, 1995). Bloswick and Chaffin (1990) have reported that required hand grip forces to climb a conventional ladder increase with increasing angle of the ladder. It can be speculated that climbing a caving ladder would require high levels of muscle activation due to the vertical, unstable position of the ladder. However, to our knowledge there have been no published papers identifying the EMG activity of the upper body musculature during rope or caving ladder climbing activities.

Early discussions with police hierarchy highlighted some concern that rope pull-up ability was influenced by between-subject differences in height; with the belief that taller individuals might struggle more with the rope pull-up task. However, to our understanding, there is no published research supporting this claim. Previous research has found that participants whose upper arms were longer and had greater girth were stronger and more powerful during horizontal bench press exercises (Argus, Gill, Keogh, & Hopkins, 2014). This indicates that the taller individuals may not struggle during the rope pull-up as previously believed; however, direct comparisons are difficult to make due to differences in exercise.

Electromyographic analysis of the rope and ship's ladder climb, along with analysis of the rope pull-up exercise is required to compare the associated muscle activity between tasks. This will provide evidence of whether the rope pull-up is a suitable assessment of operational climbing ability among the uniformed services. It is important that testing is relevant to occupational requirements to ensure the upmost safety of officers, and avoid physical testing being labelled as discriminatory (Payne & Harvey, 2010). While there is similarity in the pull-up and pull-down movements, the aforementioned findings indicate that the exercises should not be used interchangeably (Johnson, Lynch, Nash, Cygan, & Mayhew, 2009). Limited research of the pull-up, and some conflicting results, corroborates that further research is required to establish the pattern and degree of muscle activation (Leslie & Comfort, 2013).

9.2. Electromyographic analysis during front and side bridge exercises

9.2.1. Introduction

Uniformed services (especially the military) are often required to perform physical activity carrying heavy loads for prolonged durations (Jones & Knapik, 1999). In order to maintain the spine in neutral alignment during load carriage the core muscles must increase muscle activity to overcome the external resistance (Borghuis et al., 2008). As such, core endurance tests are beneficial to assess the ability to perform load carriage activities (Jones & Knapik, 1999; McGill et al., 2003). The most commonly used assessment is a sit-up or trunk curl test (ACSM, 2010; Cuddy et al., 2011); however, these tests only give an indication of anterior and side core muscular endurance (Burden & Redmond, 2013; Escamilla et al., 2006). As sit ups may result in compressive forces in the spine exceeding 3000N, this mode of exercise is not suitable for most population groups (McGill, 2001). *In vitro* studies have shown that modest compressive forces of 1472N combined with repetitive flexion/extension motions significantly increases the risk of intervertebral disc herniation (Callaghan & McGill, 2001). Consequently, isometric core endurance tests, such as the bridge, have been recommended due to the neutral spine position eliciting lower compressive forces (Marshall, Desai, & Robbins, 2011; McGill, 2001).

The STG tests core endurance by utilising a combination of two bridging exercises. The test involves 30 second rotations between prone and side bridge positions (Figures 9.3a & 9.3b) for a duration of 12 minutes. While literature identifies the muscle activity associated with individual elements of the STG bridge test (Ekstrom, Donatelli, & Carp, 2007; Garcia-Vaquero, Moreside, Brontons-Gil, Peco-Gonzalez, & Vera-Garcia, 2012; Lehman, Hoda, & Oliver, 2005), there is a lack of empirical evidence which has validated the use or length of time, of the rotational bridge. A literature search was performed between 8/08/2014-22/08/2014 utilising the SPORTDiscus, Web of Knowledge, PubMed and Google Scholar databases initially searching key terms ‘core stability’ or ‘core endurance’ or ‘core strength’ and test or assessment. Once a broad understanding of the literature surrounding this area was gained, a refined search utilising the key terms ‘prone hold’ or ‘prone bridge’ or ‘front bridge’ or plank or ‘side hold’ or ‘side bridge’ or ‘side plank’ combined with EMG or electromyography or ‘muscle activ*’ was performed. A total of 18 articles were retrieved.

Figure 9.3a. Correct position during the prone bridge exercise maintaining neutral spine alignment. Brian Reddy. (2013). *Arm positioning during the plank exercise* [Photograph]. Retrieved from b-reddy website: http://b-reddy.org/2012/11/15/arm-positioning-during-the-plank-exercise/

Figure 9.3b. Correct body position maintaining neutral spine alignment during the side bridge exercise. Ride On. (2013). *Side bridge* [Photograph]. Retrieved from Ride On website: http://rideons.wordpress.com/2012/12/18/strong-lean-riding-machine/side-bridge/

9.2.2. Core stability

The core refers to the trunk and pelvic [lumbopelvic] section of the body (McGill, 2001; Willardson, 2007). The lumbopelvic section consists of various structures to provide a foundation allowing for movement, support and protection (Panjabi, 1992). Two fundamental components to core stability include muscular endurance[5] and muscular strength[6] (ACSM, 2010). Passive, active and neural subsystems work to ensure stability of the spine and to provide force for various activities (Panjabi, 1992). Core stability has been recognised as extremely important in physical performance, enhancing ability to perform activities of daily living [ADL], and to reduce injury during ADL, sporting activities and during periods of prolonged heavy physical work (Borghuis et al., 2008). However, the required degree of muscle activation is highly dependent on the general activities performed by an individual.

Spinal ligaments, facet joints and muscle tendons constitute the passive subsystem of the core (Willardson, 2007). *In vitro* studies observed these passive structures to only support very low compressive loads (90N), therefore requiring support from the active subsystem which is comprised of global and local muscles grouped by their role in stabilising the spine (Borghuis et al., 2008). Global stabilisers are generally large and superficial, and are dynamic, phasic and torque producing (Akuthota & Nadler, 2004; Borghuis et al., 2008; Hibbs, Thompson, French, Wrigley, & Spears, 2008); these muscles include the rectus abdominis, external obliques, internal obliques (anterior fibres), erector spinae and lateral portion of the quadratus lomborum (Figures 9.4a & 9.4b) (Anderson & Behm, 2005; Willardson, 2007). In conjunction, the

---

[5] Muscular endurance is the ability of a muscle or muscle group to sustain repeated contractions, or maintain a position for a period of time.
[6] Muscular strength is the maximal force produced by a muscle or muscle group in order to overcome resistance.

local stabilisers are generally deep muscles that are postural, tonic and segmental stabilisers, including the: multifidi; transversus abdominis; diaphragm; quadratus lomborum (medial aspect); internal obliques (posterior fibres); and inter-spinal muscles (Akuthota & Nadler, 2004; Anderson & Behm, 2005; Willardson, 2007). Finally, the neural subsystem continuously monitors and adjusts intra-abdominal pressure through feedback mechanisms of muscle spindles, Golgi tendon organs and spinal ligaments (Willardson, 2007). The aforementioned subsystems are essential to maintain posture, and provide optimal function during both ADL and activities involving high force production (Anderson & Behm, 2005). Bridging exercises are utilised to recruit the global stabilisers of the active subsystem as well as increase intra-abdominal pressure via the feedback mechanisms of the neural subsystem.

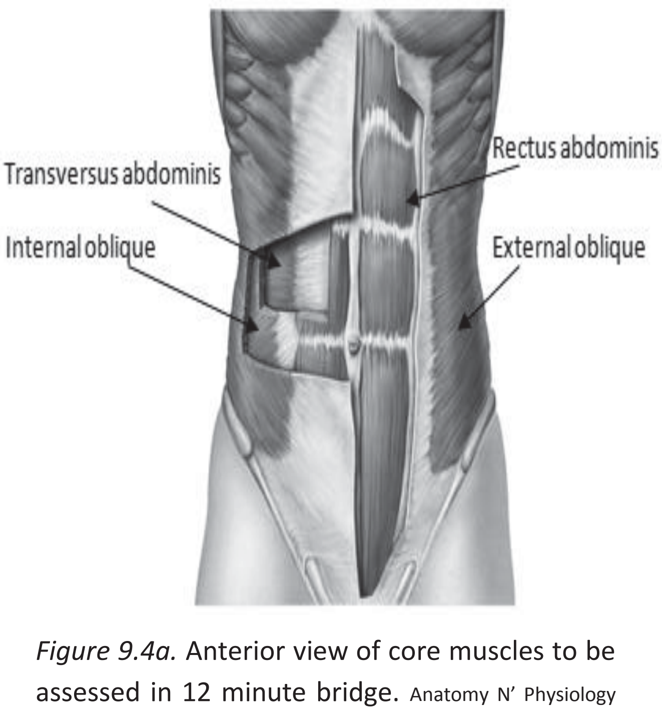

Figure 9.4a. Anterior view of core muscles to be assessed in 12 minute bridge. Anatomy N' Physiology for you. (2013). Important skeletal muscles [Image]. Retrieved from anatomy n' physiology for you website: http:// http://anatomynphysiologyforyou.weebly.com/important-skeletal-muscles

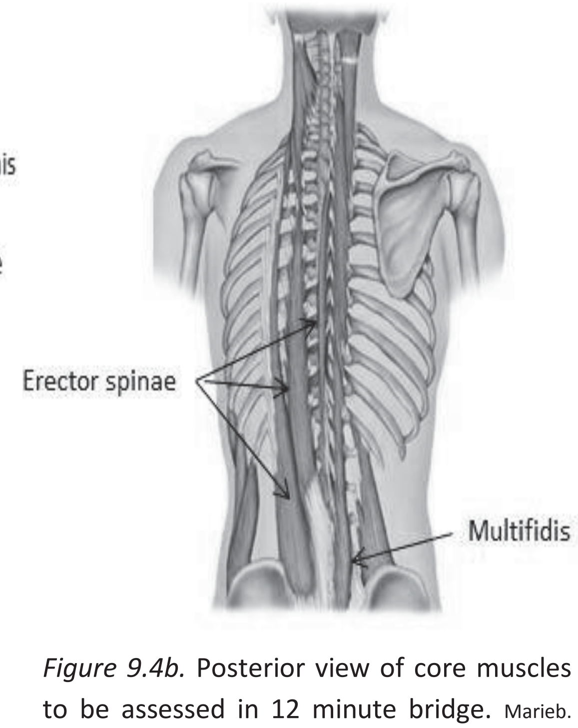

Figure 9.4b. Posterior view of core muscles to be assessed in 12 minute bridge. Marieb. (2013). Essentials of human anatomy and physiology [image]. Retrieved from: http://web.uaccb.edu

9.2.3. Muscle activity

The analysis of signal data provides information about the degree of muscle activation associated with a specific activity. To understand the influence of normalised EMG activity, muscle activity can be grouped into relative levels of activation through the previously defined classifications: low (< 20 %MVIC); moderate (20-40 %MVIC); high (41-60 %MVIC); and very high (> 60 %MVIC) (Digiovine, Jobe, Pink, & Perry, 1992). It is generally agreed that a level of 50-60 %MVIC is required to promote muscular strength adaptations (Andersen et al., 2006; Digiovine et al., 1992).

9.2.3a. Prone bridge

The prone bridge is a common core endurance exercise utilised to improve core stability. This exercise also functions as a test of core stability by challenging a participant to maintain neutral spine position, against gravity, over a period of time (Cowley, Fitzgerald, Sottung, & Swensen, 2009). To our knowledge, Lehman, Hoda and Oliver (2005) were the first to analyse normalised EMG data during a front bridge activity. Eleven resistance trained males performed prone and side bridge activities on and off a Swiss ball; with surface EMG recordings taken from the rectus abdominis, external oblique, internal oblique and erector spinae. Normalised with manual muscle testing techniques, muscle activation during the prone bridge on a stable surface was 27, 45, 30 and 5 % of maximal voluntary isometric contraction [%MVIC], respectively (Lehman et al., 2005). It was observed that during prone bridging on an unstable surface (Swiss ball) there was significantly greater activation of the rectus abdominis and external oblique (Lehman et al., 2005). Similarly, research performed by Garcia-Vaquero et al. (2012) and Tong, Wu, and Nie (2013) observed comparable activation of the rectus abdominis muscle of 30 and 33 %MVIC, respectively. However, greater rectus abdominis activity (43 & 52 %MVIC) has also been reported (Ekstrom et al., 2007; Schellenberg, Lang, Chan, & Burnham, 2007). Interestingly, two studies have identified similar activity of the external oblique (47 & 45 %MVIC) (Ekstrom et al., 2007; Lehman et al., 2005); however, higher (59 %MVIC) and lower (32 & 20 %MVIC) peak muscle activity have also been reported (Garcia-Vaquero et al., 2012; Schellenberg et al., 2007; Tong et al., 2013).

The differences in muscle activation between studies are likely to be associated with techniques used to obtain MVIC, and placement of electrodes. As shown in table 9.2, Garcia-Vaquero et al. (2012) and Tong et al. (2013) utilised the same electrode positioning, eliciting similar muscle activation. However, the greater muscle activation recorded by Ekstrom et al. (2007) could be explained through differing electrode placement avoiding the thickest layer of adipose tissue. Adipose tissue has been shown to attenuate the amplitude of EMG signal as it is a poor conductor of electrical activity (Nordander et al., 2003); hence, avoiding the thickest layer of subcutaneous fat may explain some of the variance observed between studies. Table 9.3 details the muscle activity associated with the aforementioned studies. All four retrieved articles analysing activity of the erector spinae during the prone bridge reported similar values ranging between 3 and 6 %MVIC (Ekstrom et al., 2007; Garcia-Vaquero et al., 2012; Lehman et al., 2005; Tong et al., 2013).

Table 9.2. Placement of core electrodes for prone and side bridge studies.

Study (y)	electrode spacing	RA	EO	ES	IO	Multifidus	G. Medius	G. Maximus
Ekstrom et al. (2007)	20mm	3cm lateral & 3cm superior to umbilicus (avoids thickest adipose tissue)	Midway between ASIS and rib cage	4cm lateral to L1 spinous process	-	2cm lateral to lumbosacral junction	anterosuperior to G.max, and inferior to iliac crest on lateral pelvis side	centre of muscle belly (lateral edge of sacrum & posterosuperior edge of greater trochanter
Garcia-Vaquero et al. (2012)	30mm	3cm lateral to umbilicus	approx 15cm lateral to umbilicus	3cm lateral of L3 spinous process	centre of triangle formed by inguinal ligament, outer edge of rectus sheath and line from ASIS to umbilicus	-	-	-
Hibbs et al. (2011)	10mm	3cm lateral and 5cm superior to umbilicus	3cm above iliac crest (level with umbilicus)	3cm lateral to L2 spinous process	2cm inferomedial to the ASIS	3cm lateral to L4-5 interspace	-	Centre of muscle belly
Juker et al. (1998)	25mm	3cm lateral to umbilicus	15cm lateral to umbilicus at transverse level	3cm lateral to L3 spinous process	below EO electrode and just superior to inguinal ligament	-	-	-
Lehman et al. (2005)	NS	NS	NS	lateral of L3	NS	-	-	-
Marshall et al. (2011)	20mm	3cm superior and 2cm lateral of umbilicus	above ASIS and lateral to umbilicus	3cm lateral to L4-5 spinous process	-	-	-	-
Schellenberg et al. (2007)	NS	NS	NS	-	-	-	-	-
Tong et al. (2013)	76mm	3cm lateral to umbilicus	Midway between ASIS and rib cage	2cm lateral to L4-L5 interspace	-	-	-	-
Youdas et al. (2008)	22mm	2cm lateral from umbilicus	Midway between ASIS and inferior point of costal margin of ribs	-	centre of triangle formed by inguinal ligament, outer edge of rectus sheath and line from ASIS to umbilicus	-	-	-

NS = not stated; Y = year; RA = rectus abdominis; EO = external oblique; ES = erector spinae; IO = internal oblique; G = gluteus.

Table 9.3. A summary of mean hold times and EMG recordings (± SD) expressed as %MVIC during the prone bridge exercise.

Study (y)	no. of subjects & training status	sex	mean hold times (s)	RA	EO	ES	IO	Multifidus	G. Medius	G. Maximus
Durall et al. (2012)	60 healthy	M, F	92 ± 44	-	-	-	-	-	-	-
Ekstrom et al. (2007)	30 healthy	M, F	-	43 ± 21	47 ± 21	6 ± 4	-	5 ± 4	27 ± 11	9 ± 7
Garcia-Vaquero et al. (2012)	29 healthy	M, F	-	30 ± 29	20 ± 17	4 ± 6	16 ± 10	-	-	-
Lehman et al. (2005)	11 active	M	-	27 ± 11	45 ± 15	5 ± 1	30 ± 19	-	-	-
Nuzzo & Mayer (2013)	83 firemen	M	140 ± 56	-	-	-	-	-	-	-
Schellenberg et al. (2007)	43 healthy	M, F	73 ± 33	52 ± 23	59 ± 27	-	-	-	-	-
Sellentin & Jones (2012)	8 army	M	(pre) 173	-	-	-	-	-	-	-
			(post) 227	-	-	-	-	-	-	-
Tong et al. (2013)	36 athletic	M, F	-	33 ± 11	32 ± 9	3 ± 1	-	-	-	-
stage 8			-	63 ± 8	55 ± 7	5 ± 2	-	-	-	-

y= year; M= male, F= female; RA= rectus abdominis; EO= external oblique; ES= erector spinae; IO= internal oblique; G=gluteus

9.2.3b. Side bridge

The side bridge requires an individual to brace one elbow directly beneath the shoulder with the lateral aspect of the ipsilateral foot resting on the ground. The pelvis is then raised to maintain a straight midline of the body as shown in Figure 9.3b. This exercise is commonly used in the rehabilitation setting as it provides activation of the spine extensors without large compressive forces (Garcia-Vaquero et al., 2012; Marshall et al., 2011). Various studies have identified the muscle activity associated with side bridge exercises to validate the use as either a rehabilitation exercise or sport performance test (Hibbs et al., 2008).

Juker, McGill, Kropf and Steffen (1998) quantitatively analysed the muscle activity associated with the side bridge. Intramuscular electrodes were inserted into the psoas, external oblique, internal oblique and transversus abdominis; as well as surface electrodes placed on the rectus abdominis, external oblique, internal oblique, erector spinae and rectus femoris. Participants then performed a variety of tasks including a range of lifting activities, and core endurance exercises including the side bridge. As detailed in table 9.5, greatest activation of core stabilisers during the side bridge occurred in the external oblique (43 %MVIC), transversus abdominis (39 %MVIC) and internal oblique (36 %MVIC); followed by the erector spinae (24 %MVIC) and rectus abdominis (22 %MVIC) (Juker et al., 1998). This research also supported previous research performed by McGill, Juker and Kropf, (1996), validating the use of well-placed surface EMG to reflect the activity of deep spinal stabilisers.

Three studies have also reported similar activation of the rectus abdominis with EMG recordings ranging from 19 to 24 %MVIC (Lehman et al., 2005; Marshall et al., 2011; Youdas et al., 2008). Higher recorded values by Hibbs, Thompson, French, Hodgson and Spears (2011) (43 %MVIC) and Ekstrom et al. (2007) (34 %MVIC) can be attributed to electrode placement being superior to the umbilicus, therefore avoiding the thickest part of adipose tissue. Comparable data to the Juker et al. (1998) study for external oblique activity was reported by Lehman et al. (2005) (46 %MVIC) and Youdas et al. (2008) (51 %MVIC). In contrast, three studies recorded greater activation of the external oblique with values of 69, 71 and 72 %MVIC, respectively (Ekstrom et al., 2007; Hibbs et al., 2011; Marshall et al., 2011). Finally, one study has reported low activation (20 %MVIC) of the external oblique during the side bridge (Garcia-Vaquero et al., 2012). While between study design varied on methods utilised to obtain electrode placement for the external oblique (table 9.3), each would have ended up with a similar reference point; furthermore, some studies that had higher EMG recordings utilised the exact method as those who reported lower readings.

Activity of the erector spinae was similar across three studies with values of 18, 24 and 26 %MVIC, respectively (Garcia-Vaquero et al., 2012; Juker et al., 1998; Lehman et al., 2005). Three studies also reported muscle activity that was higher than the aforementioned with values of 40, 47 and 57 %MVIC (Ekstrom et al., 2007; Hibbs et al., 2011; Marshall et al., 2011). Interestingly, only two studies analysed the activity of the multifidus which has been recognised as an important local stabiliser of the spine (Anderson & Behm, 2005); similar values of 42 and 47 %MVIC were reported (Ekstrom et al., 2007; Hibbs et al., 2011). It is important to note that the highest activation of all muscles occurred on the ipsilateral side to which the bridge was being performed (Ekstrom et al., 2007).

9.2.3c. Summary of prone and side bridge EMG

Based on previous classifications outlined by Digiovine et al. (1992), table 9.4 details the relative activation of the aforementioned research between prone and side bridge positions.

Table 9.4. Relative activation of core musculature between prone and side bridge positions.

Position	RA	EO	ES	IO	Mul	G. Medius	G. Maximus
Prone	Mod-high	High	Low	Low-mod	Low	Mod	Low
Side	Low-mod	High-very high	Mod-high	Mod-high	High	Very high	Mod

Mod = moderate; RA = rectus abdominis; EO = external oblique; ES = erector spinae; IO = internal oblique; Mul = multifidus; G = gluteus.

9.2.3d. Combined core stability exercises

Tong et al. (2013) validated a sport specific core endurance test which involved starting in the prone position for 60 seconds [stage 1], then lifting one limb after the other off the ground for 15s [stage 2-5], followed by assuming both superman positions (lifting opposing upper and lower limbs) for 15s each side [stage 6 & 7], then returning to the prone bridge for the final 30s [stage 8] (Mackenzie, 2005). As shown in table 9.2, muscle activity of the rectus abdominis and external oblique was significantly greater during the prone bridge upon completion of rotation through the differing elements of the core endurance test. The authors infer that greater motor unit recruitment was required to maintain neutral spine alignment in stage eight, counteracting the muscle fatigue that was augmented by different muscle activation patterns of the preceding stages (Tong et al., 2013).

Table 9.5. A summary of mean hold times and EMG recordings (%MVIC) during the side bridge exercise.

Study (y)	no. of subjects and training status	sex	mean hold time (s)- R	mean hold time (s)- L	RA	EO	ES	IO	Multifidus	G. Medius	G. Maximus
Ekstrom et al. (2007)	30 healthy	M,F	-	-	34 ± 13	69 ± 26	40 ± 17	-	42 ± 24	74 ± 30	21 ± 16
Evans et al. (2007)	24 athletic	M,F	104.8 ± 44.1	103.0 ± 41.3	-	-	-	-	-	-	-
Garcia-Vaquero et al. (2012)	29 healthy	M,F	-	-	14 ± 8	20 ± 13	18 ± 8	-	-	-	-
Hibbs et al. (2011)	11 athletic	M	-	-	43 ± 11	71 ± 25	47 ± 17	58 ± 29	47 ± 10	-	-
Juker et al. (1998)	8 healthy	M,F	-	-	22 ± 13	43 ± 13	24 ± 15	36 ± 29	-	-	-
Lehman et al. (2005)	11 active	M	-	-	24 ± 12	46 ± 15	26 ± 11	43 ± 25	-	-	-
Marshall et al. (2011)	10 active	M,F	-	-	19 ± 5	72 ± 9	57 ± 11	-	-	-	-
McGill et al. (1999)	75 healthy	M,F	81 ± 34	85 ± 36	-	-	-	-	-	-	-
Sellentin & Jones (2012)	8 army	M	(pre) 79	(pre) 123	-	-	-	-	-	-	-
			(post) 106	(post) 103	-	-	-	-	-	-	-
Youdas et al. (2008)	22 healthy	M,F	-	-	20 ± 17	51 ± 6	-	39 ± 50	-	-	-

y= year; M= male, F= female; R= right, L= left; RA= rectus abdominis; EO= external oblique; ES= erector spinae; IO= internal oblique; G= gluteus.

McGill and Karpowicz (2009) sought to validate progressions of commonly used core stability exercises. One of these exercises was the side bridge, with the most challenging progression a transition from the side position to the opposite side position; much the same as the STG bridge test but without the 30 second hold in the prone position. When in the side position muscle activity of the external oblique was less than 20 %MVIC, however while rolling to the opposite side muscle activity of the rectus abdominis and external oblique approached 50 %MVIC on both the left and right sides (McGill & Karpowicz, 2009). Significant increases were also observed in the latissimus dorsi and upper and lower portions of the erector spinae indicating that rolling out of and into a side bridge substantially challenges all measured muscles (McGill & Karpowicz, 2009). Whilst muscle activation was high, participants were only required to perform one repetition of the manoeuvre.

9.2.3e. Mean hold times

As bridging exercises are used to assess core endurance the literature search was extended to include studies investigating mean hold times. Not surprisingly, those who require greater levels of core stability, due to occupational demands (Nuzzo & Mayer, 2013; Sellentin & Jones, 2012), demonstrated greater maximal hold times in comparison to healthy adults (Durall, Greene, & Kernozek, 2012; Schellenberg et al., 2007). Maximum hold times during the prone position range from 73 seconds to 227 seconds. Evans, Refshauge and Adams (2007) reported a mean hold time during the side bridge of 105 ± 44 seconds for the dominant side in an athletic population. Sellentin and Jones (2012) also reported a similar value of 106 seconds in soldiers following a core endurance training programme, while McGill, Childs and Liebenson (1999) have recorded values of 81 seconds in general healthy populations. Mean hold times for side bridges do not vary significantly between left and right sides.

9.2.4. Manual muscle testing

The main factor associated with differences in muscle activity between studies, when similar electrode placement was utilised, is most likely the method applied to obtain MVIC. Manual muscle testing techniques are often used in EMG studies to normalise data to a standard reference representing 100 % of maximum muscle activation. This technique involves the experimenter providing manual resistance against a muscle in a set position, whilst the participant performs maximal isometric contraction of that particular muscle. This normalisation technique was used in all but one study discussed (Lehman et al., 2005). In these studies the MVIC may be influenced by the exercise chosen, experience of the individual providing manual resistance, participant motivation, pain and the ability of the participant to produce maximal force (Ekstrom, Soderberg, & Donatelli, 2005; Hibbs et al., 2011). These factors likely contribute to variation in muscle activity between studies when the electrode placement is controlled for. Despite the aforementioned variance which may occur during MVIC testing, manual muscle testing has been validated as a normalisation technique, with small variability between measurements accepted (Bolgla & Uhl, 2005; Ekstrom et al., 2005; Hibbs et al., 2011). Furthermore, the technique is more suitable in well trained versus untrained participants (Hibbs et al., 2011); and favourable when testing a variety of muscles in limited timeframes.

Variability between participants can be minimised by maintaining the isometric position for a period of time and performing multiple sets, with adequate rest. The aforementioned studies utilised different protocols to obtain MVIC, making comparisons between studies difficult. Tong et al. (2013) and Youdas et al. (2008) only performed one set for each exercise which may present unreliable data in reference to MVIC; however, the employed isometric hold time of five seconds is perceived as optimal to ensure maximum force is produced. Conversely, Ekstrom et al. (2005) performed three sets with an isometric hold of five seconds, but the short rest period of 30 seconds between sets may result in accumulative muscle fatigue, thus decreasing maximal force production in subsequent trials. Set guidelines to obtain MVIC need to be employed to reduce variability. From the current literature it is summarised that performing familiarisation followed by 2-3 sets per exercise, held for five seconds with 1-2 minutes rest is optimal (Ekstrom et al., 2005; Tong et al., 2013; Youdas et al., 2008).

9.2.5. Reporting EMG data

Peak EMG are often presented as a measure of maximal muscle activity over the duration of measurement (Hibbs et al., 2011). While this is beneficial when measuring strength based exercises, it has been suggested (Hibbs et al., 2011) that average rectified variable [ARV] EMG may be more suited to core stability exercises, as this method can detect any perturbations of muscle activity that occur with stabilisation (Hatton et al., 2009). This is because ARV EMG gives the mean EMG signal amplitude over a set time window. Average rectified variable EMG is obtained by calculating the mean area under the processed EMG curve, and dividing this by an elapsed time window (Hibbs et al., 2011). Results from Hibbs et al. (2011) show ARV EMG data to be significantly less variable. Furthermore, the use of ARV EMG also allows the detection of fatigue through analysis of EMG signal firing frequency over the designated time window (Kumar et al., 2003).

Within static contractions (such as those measured during the bridge test), muscular fatigue manifests as changes in muscle activity, and EMG signal frequency over time (Kumar et al., 2003; Yoshitake et al., 2001). Analysis of EMG signal frequency has been widely used in fatigue studies, rehabilitation and clinical diagnosis

(MacIsaac, Parker, Englehart, & Rogers, 2006; Talebinejad et al., 2009). Importantly, the frequency of EMG signal represents the firing rate of active motor units, and is considered the most important determinant of muscular fatigue (Medved & Cifrek, 2011; Talebinejad et al., 2009; Yoshitake et al., 2001).

Maintaining a static contraction causes a build-up of mechanical pressure within the muscle; with sustained contractions at intensities greater than 20 %MVIC restricting blood flow to the muscle (Barnes, 1980; Yoshitake et al., 2001). The restriction in blood flow causes muscle fatigue though the accumulation of metabolic by-products, which reduce the conduction velocity of the action potential (Barnes, 1980; Medved & Cifrek, 2011; Yoshitake et al., 2001). This is detected through a decline in EMG firing frequency (Medved & Cifrek, 2011). The major mechanical factor causing fatigue in the muscle is a decline in the excitation-coupling process of actin and myosin filaments (Giannesini et al., 2003). Research performed by Kent-Braun (1999) examined the effect of metabolite accumulation on force production during sustained isometric contractions. A strong correlation was observed between the intramuscular pH and the decline in force production; indicating that metabolite accumulation inhibits the contractile process (Kent-Braun, 1999). Similar results have also been reported elsewhere (Cady, Jones, Lynn, & Newham, 1989; Laurent, Portero, Goubel, & Rossi, 1993).

In order to counteract the reduction in firing frequency, there is an increase in muscle fibre recruitment, detected by a rise in EMG signal amplitude (Medved & Cifrek, 2011). The influence of muscle fatigue increasing EMG signal amplitude needs to be taken into consideration when utilising peak EMG for core stability assessments. Hence, ARV EMG provides more reliable data regarding the level of muscle activation during the bridge test. Additionally, analysis over a designated time window permits the detection of muscular fatigue through EMG signal frequency analysis.

9.2.6. Summary

Core stability is an important physical trait for uniformed personnel to possess, as it is associated with reduced risk of injury during operational tasks (Borghuis et al., 2008). Previous research infers that the 12 minute bridge test serves as a good core endurance assessment of all major core stabilisers. This is due to due to rotation between side and prone positions engaging posterior and anterior core musculature, respectively. However, it seems necessary to utilise ARV EMG analysis to detect any perturbations that occur with stabilisation during the bridge positions, and to examine the effect of muscular fatigue over the 12 minute duration. Based on the aforementioned research, relative activation of the rectus abdominis is highest during the prone position; whereas activation of external oblique, internal oblique, erector spinae and multifidus is highest during the side bridge position. Although data is scarce, the gluteus medius and gluteus maximus have higher activation during the side bridge.

Previous research (Hibbs et al., 2011; McGill & Karpowicz, 2009; Tong et al., 2013) suggests that muscle activation over the 12 minute duration of the STG bridge test will increase from already high levels associated with the rolling manoeuvre, potentially leading to significant fatigue of the core musculature (McGill & Karpowicz, 2009; Tong et al., 2013).

10. METHODOLOGY

10.1. Participants

All STG members were sent a cover letter (Appendix E) and information sheet (Appendix F) seeking participants to partake in this research. A total of 19 male STG members (mean ± SD; 40 ± 5 y, 184 ± 5 cm, 93.6 ± 7.4 kg, 25.4 ± 1.9 kg·m²) volunteered to participate in this research. Participants were free from any musculoskeletal injury hindering participation in the tasks to be completed (refer Appendix G & H), and provided written informed consent prior to participation (refer Appendix I). Research was conducted in agreement with the guidelines and policies of the human ethics committee of Massey University (refer Appendix J).

10.2. Instrumentation

Raw EMG signals were collected with TeleMyo DTS (Noraxon, Arizona, USA) wireless surface EMG sensors. Electromyographic signals were detected by electrodes (Ambu, BlueSensor, Denmark) with an inter-electrode spacing of 20 mm. Signals from the transmitter devices affixed to the skin were sent to a central receiver via Bluetooth. Data was collected at a sampling rate of 1000 Hz. Raw EMG signals were processed and analysed using MyoResearch XP (Noraxon, Arizona, USA). A high definition camera (Logitech, HD C615, Switzerland) sampling at 30 Hz was synchronized to the EMG recording device for analysis purposes.

10.3. Procedures

Each participant performed the field based fitness assessments over three consecutive days. All testing was conducted at specialised Police training facilities. Prior to testing, anthropometric measurements of height, body mass, upper and lower arm length were obtained. Limb length was measured with a segometer (realmetbcn, Barcelona, Spain) with participants standing in the anatomical position. The upper arm was measured from the acromion to the head of the radius, and lower arm length measured from the head of the radius to the lateral styloid process; the addition of these two measurements gave total limb length (Norton & Olds, 2004).

All electrodes were placed on the hand-dominant side. Prior to electrode placement each participant's skin was shaved of any hair with a disposable single use razor, and vigorously cleansed with alcohol wipes until erythema was attained (Konrad, 2006). Electrodes were then affixed to the skin over the muscle belly, and running parallel to the fibre direction, as outlined in the reputable guidelines of surface electromyography for the non-invasive assessment of muscles [SENIAM], and others (Merletti & Hermens, 2000) (refer Appendix K & L). New electrodes were used on each testing day; normalisation was also performed on each testing day.

Prior to data collection, and to ensure normalisation, participants performed MVIC's, for each 'EMG' assessed muscle group (Ekstrom et al., 2007; Garcia-Vaquero et al., 2012; Hislop, Avers, Brown, & Daniels, 2014; Lehman et al., 2005; Vera-Garcia, Moreside, & McGill, 2010; Youdas et al., 2008). Normalisation required participants to produce a maximal isometric contraction of a muscle, with the maximal contraction serving as a standard reference to 100 % of muscle activation (Konrad, 2006). This gave an indication between the scale of EMG signal detected and maximal amount of EMG signal a participant can produce; thus allowing comparison between participants, muscles or activities (Ekstrom et al., 2007). Each MVIC was performed using muscle testing techniques detailed elsewhere (see Appendix M & N). Following familiarisation, participants performed three MVIC's per muscle, against resistance provided by the researcher. All muscles were tested in a randomised order; each contraction was held for five seconds, with one minute rest between each repetition (Hibbs et al., 2011; Youdas et al., 2008).

10.3.1. Rope pull-up

Muscles for EMG analysis in the upper body tasks included: upper pectoralis major; biceps brachii; brachioradialis; mid-deltoid; mid-trapezius; lower trapezius; latissimus dorsi; and infraspinatus as shown in Figure 9.2a and 9.2b (refer Appendix K). Following a standardised warm-up (refer Appendix O), participants were required to perform one of the following three upper body tasks. On day two of testing, participants were required to perform the remaining two upper body tasks. A five minute rest period was used between tasks to eliminate the effect of muscular fatigue on EMG signal (Kumar et al., 2003; Tomlin & Wenger, 2001). Each task was performed in a randomised order. Synchronised video and EMG were continuously recorded during each task.

10.3.1a. Rope pull-ups

The rope pull-ups were performed on two lengths of rope (diameter = 32 mm, length = 150 mm), separated 150 mm apart, with knotted ends. Participants were required to perform one set of maximal repetitions until technique became significantly impaired. Each repetition started with the participant hanging with their arms straight (Figure 10.1a). The participants were then required to pull their body mass upwards until the elbows were at the side of their body and pointing directly downwards (Figure 10.1b); the repetition was completed upon return to starting position.

10.3.1b. Ladder climb

The ladder climb was performed on a six metre suspended caving ladder (width: 150 mm, step spacing: 250 mm, rung diameter: 12.5 mm). Participants were required to ascend and descend the caving ladder twice with proper technique, and separated by five minutes rest to limit fatigue (table 10.1).

Figure 10.1a. Bottom position of the rope pull-up.

Figure 10.1b. Top position of the rope pull-up.

10.3.1c. Rope climb

The rope climb was performed on a standard climbing rope (diameter = 50.8 mm), suspended from a purpose built training rig. Participants were required to ascend and descend the rope twice, with proper technique, to a height of six metres. Each trial was separated by a five minute rest period (table 10.1). Leg assistance was permitted in each climbing task, as per regular (correct) climbing technique.

10.3.2. Bridge test

The 12 minute bridge test was performed on day three of testing. Muscles for EMG analysis were: rectus abdominis; external oblique; internal oblique; multifidus;

lumbar and thoracic portions of the erector spinae; latissimus dorsi; and the mid-deltoid as shown in Figures 9.4a and 9.4b (refer Appendix L). Following a standardised warm up (refer Appendix O), the test started in the prone bridge position for 30 seconds (Figure 10.2a), participants then rotated to the hand-dominant side and held for 30 seconds (Figure 10.2b), then returned to prone for 30 seconds before rotating to the non-dominant side and maintaining for 30 seconds; this process was continued for a total duration of 12 minutes. Electromyography and video recordings were taken during the final 5 seconds, continuing into the first 5 seconds of each rotation.

Figure 10.2a. Prone position during the 12 minute bridge.

Figure 10.2b. Hand-dominant side position during the 12 minute bridge.

10.4. Data analysis

The EMG signal was amplified with a built-in differential amplifier. All raw EMG data was filtered using a Lancosh FIR digital fourth-order bandpass filter set at 10-500 Hz. The bandwidth of 10-500 Hz was selected to remove extrinsic noise sources, whilst maintaining integrity of the EMG signal. The high-pass end of 10 Hz was selected to suppress movement artefact, whilst maintaining EMG signal information pertaining to the performance of the muscle (De Luca, Gilmore, Kuznetsov, & Roy, 2010). The low-pass end of 500 Hz was selected as the predetermined point where noise surpasses the EMG signal (De Luca et al., 2010). Notch filtering at 50 Hz was used to remove power line, and fluorescent lighting noise. Following full wave rectification, the EMG data was smoothed to a 50 ms root mean square [RMS] algorithm which is common in EMG research and allows comparisons to other studies. Visual inspection of EMG signal and synchronised video recordings were used to cut and mark each phase of the tasks.

10.4.1. Rope pull-up

For analysis, the level of **peak** muscle activity during the rope pull-up was compared to the peak level of muscle activity associated with the rope and ladder climbing tasks. Peak EMG are often presented as a measure of maximal muscle activity over the duration of exercise (Figure 10.3) (Hibbs et al., 2011). For the ladder and rope climb, EMG recordings from three complete climbing cycles during each trial were used for analysis. Peak activity for each muscle was averaged across all six complete climbing cycles for each task. Each climbing cycle was also broken down into four distinct phases as detailed in Table 10.1. For the rope pull-up, peak activation was averaged over three consecutive repetitions occurring in the middle of the set, providing the most accurate representation of peak muscle activation. For the upper body tasks, the peak muscle activity observed for any normalising trial was taken as the MVIC for that particular muscle; averaged data was then expressed as a percentage of MVIC.

10.4.2. Bridge test

For the 12 minute bridge, the **average** level of muscle activation was analysed, in addition to the level of fatigue experienced. The difference in methods for analysis between the rope pull-up and 12 minute bridge is justified by the rope pull-up being a measure of strength, whereas the 12 minute bridge is a measure of strength endurance. It has been suggested that average rectified variable [ARV] EMG may be more suited to core stability exercises as this analysis method can detect any changes of muscle activity that occur with stabilisation (Figure 10.4) (Hatton et al., 2009; Hibbs et al., 2011). Furthermore, analysis of ARV EMG over a designated time window allows the level of experienced muscle fatigue to be identified through frequency analysis. This was deemed important to measure due to the duration of the 12 minute bridge test.

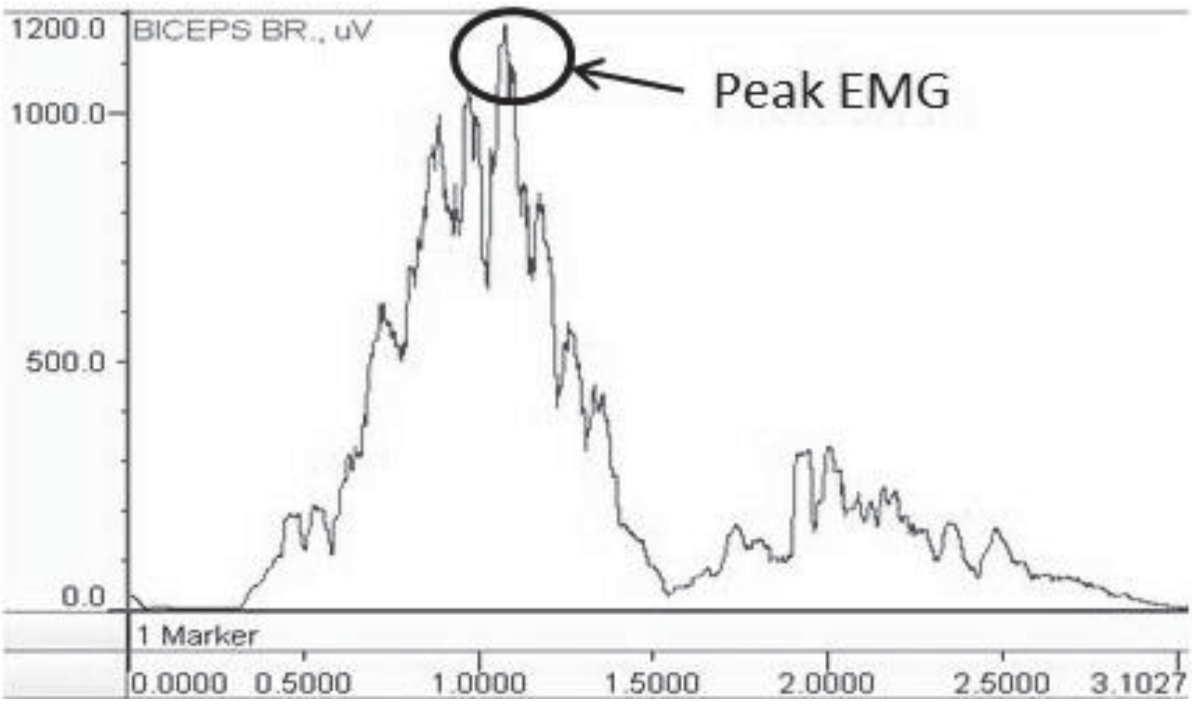

Figure 10.3. Example of muscle activity associated with the pull-up exercise, and the identification of peak muscle activation.

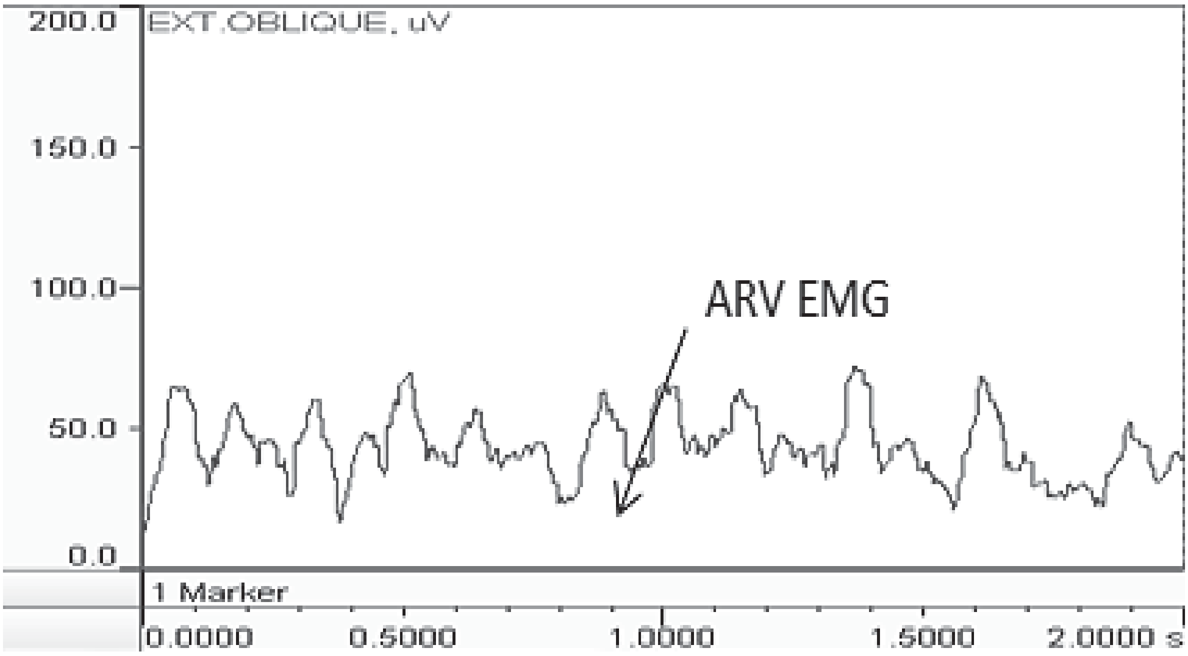

Figure 10.4. Example of muscle activity associated with the 12 minute bridge, and the identification of ARV muscle activation.

Analysis of the 12 minute bridge test utilised two EMG signal parameters including: ARV EMG data (amplitude); and median frequency. Average EMG was utilised to give an indication of level of muscle activity involved with the test. This was analysed in the final two seconds before rotation, for each position over the 12 minute duration. Visual recordings were used to ensure that participants were not initiating a postural shift within the final two seconds of each stage. The ARV amplitude was normalised to a maximal two second ARV EMG time window, obtained from the middle of the five second MVIC. Median frequency gives an indication of the level of fatigue experienced in each muscle. The frequency was also measured during the final two seconds before rotation of each position over the 12 minute duration. Median frequency was chosen for fatigue analysis as it is considered far less variable than mean frequency (Basmajian & De Luca, 1985; De Luca, 1997; Roman-Liu, Tokarski, & Wojcik, 2004). In addition, a fatigue index [FI] across the entire duration of the test was also calculated. Figure 10.5 illustrates how frequency was measured for each position and across the duration of the test (Basmajian & De Luca, 1985; De Luca, 1997; Roman-Liu et al., 2004).

10.5. Statistical analysis

All statistical analysis was completed using the statistical analysis package SPSS version 22.0 (IBM, Armonk, NY) for windows 7.

10.5.1. Rope pull-up

Pearson correlation coefficient [r] were used to determine whether there were any significant relationships between anthropometric variables (i.e., body mass, height) and the amount of repetitions performed during the rope pull-up test. A series of one-way analysis of variance [ANOVA] were used to determine if there were any statistical differences in peak muscle activity between tests (rope climb, ladder climb, rope pull-up). If statistical differences were reported, post hoc testing using a Bonferroni multiple comparison analysis was performed to identify the location of the observed difference.

10.5.2. Bridge test

Pearson correlations were undertaken during prone and dominant side bridge positions between FI and anthropometric measurements. A correlation coefficient [r] was calculated when comparing the amount of fatigue and anthropometric variables. One-way ANOVA’s were also used to compare signal frequency and average EMG amplitude over the duration of the 12 minute bridge test in prone and side positions. Where significant differences were reported, post hoc analysis using a Bonferroni multiple comparison analysis was used to identify the location of any statistical differences between stages (duration of test), for each position, specifically.

Table 10.1. Technique of each climbing cycle.

Task	Phase 1	Phase 2	Phase 3	Phase 4
Ladder climb	Left hand off ladder (uni-lateral) 	Both hands on ladder with left hand on top 	Right hand off ladder (uni-lateral) 	Both hands on ladder with right hand on top 
Rope Climb	Left hand comes off rope and re-grips on top (uni-lateral) 	Right hand off rope and re-grips on top (uni-lateral) 	Unlock legs and propel body upward 	Lock off rope with both legs 

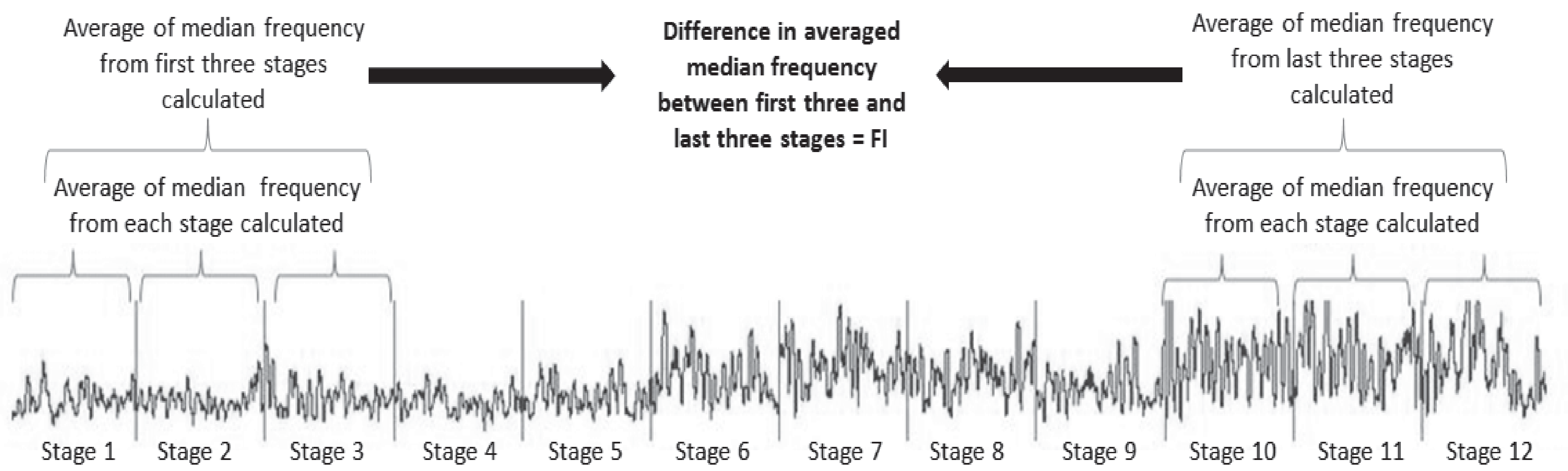

Figure 10.5. A schematic showing how to calculate a fatigue index [FI] of the 12 minute bridge test. Adapted from: Konrad, (2006). The ABC of EMG (Konrad, 2006).

11. RESULTS

11.1. Rope pull-up

11.1.1. Rope pull-up correlations

On average, each participant was able to complete 12 ± 3 rope pull-up repetitions. Significant correlations were observed between body mass and number of repetitions completed (r = -.749; *P* < .001); and BMI and repetitions completed (r = -.825; *P* < .001). As demonstrated in Figures 11.1 and 11.2, as body mass and BMI increased, the number of repetitions completed decreased. Non-significant correlations were observed between the amount of repetitions completed and the height, total arm length, and upper and lower arm length of the participants (*P* > .05).

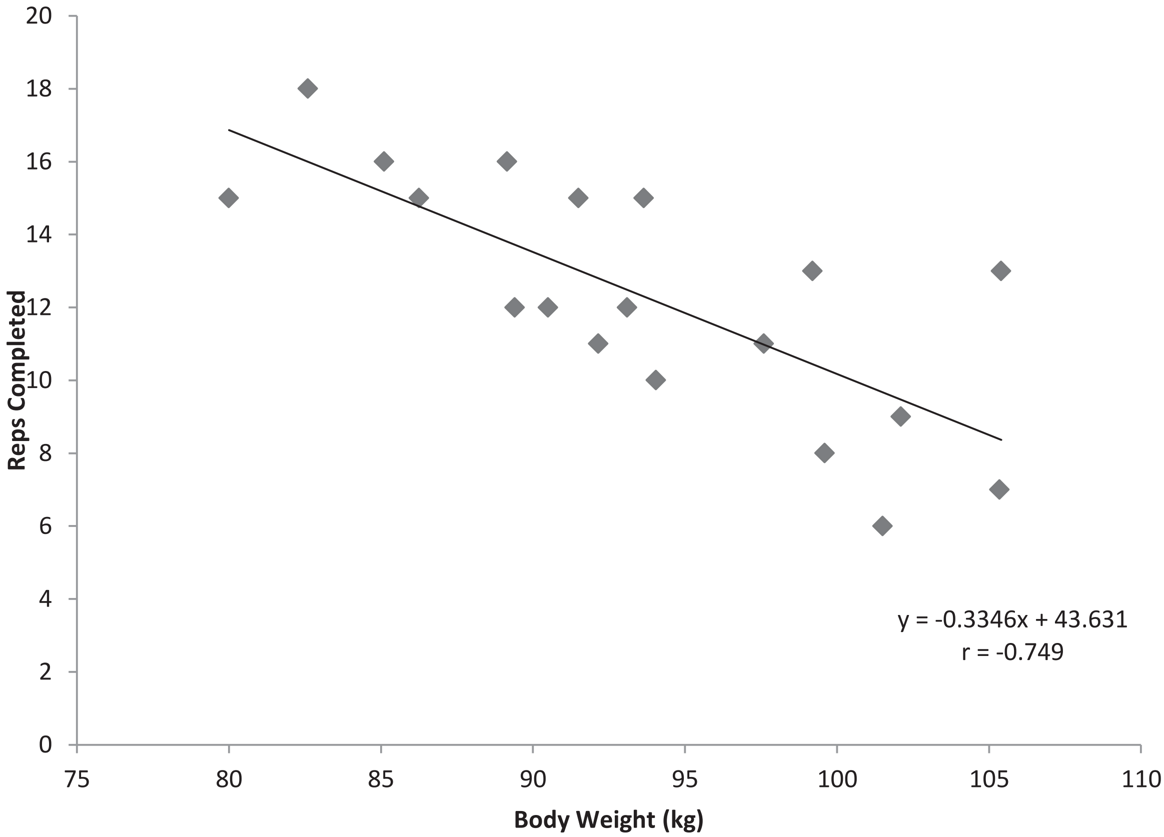

Figure 11.1 Correlation between body mass and rope pull-up repetitions completed.

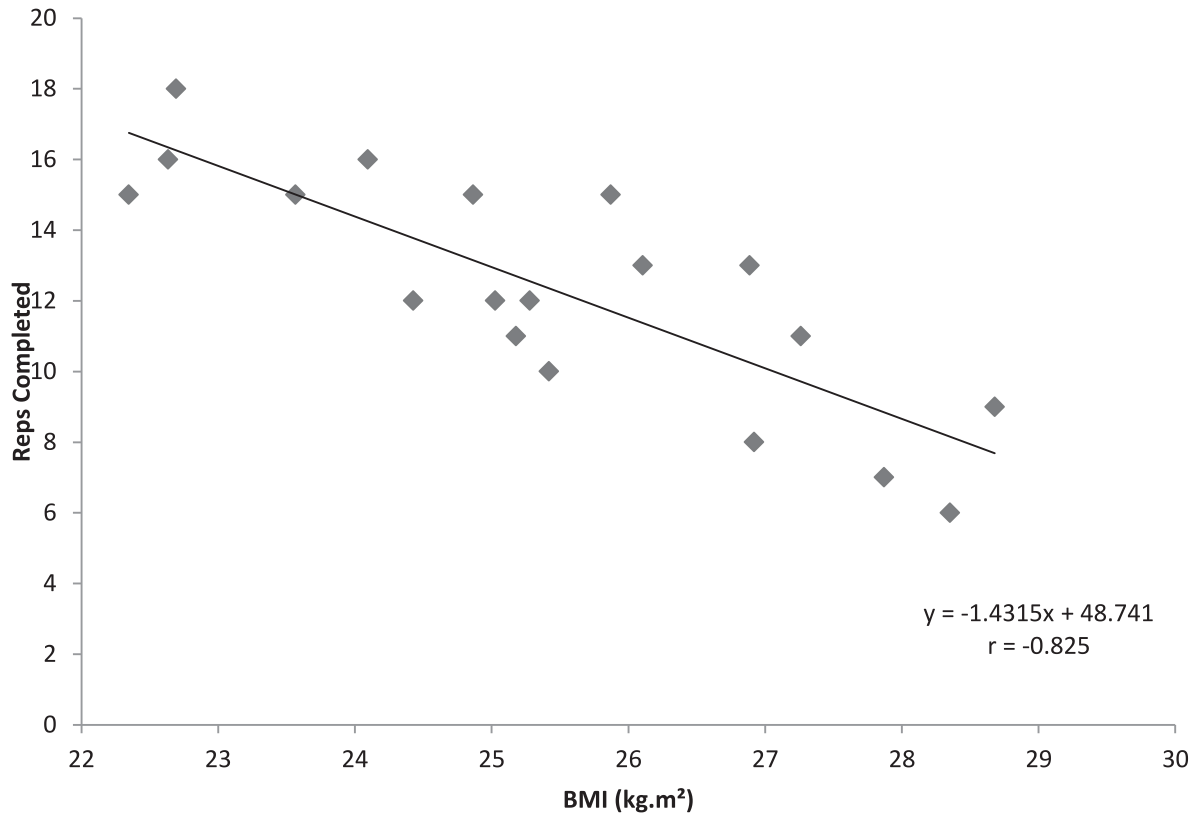

Figure 11.2. Correlation between BMI and rope pull-up repetitions completed.

11.1.2. Comparing ladder climb and rope pull-up

As demonstrated in Figure 11.3, the peak EMG data showed that the ladder climb elicited significantly greater activation of the pectoralis major compared with the rope pull-up (81.2 ± 35.4 vs. 47.1 ± 16.0 %MVIC, respectively; $P < .01$). However, peak activity in the brachioradialis, mid-trapezius and latissimus dorsi were significantly lower in the ladder climb task (all, $P < .05$).

11.1.3. Comparing rope climb and rope pull-up

Peak EMG data revealed that the rope climb elicited significantly higher activity of the pectoralis major, mid-deltoid and infraspinatus in comparison to the rope pull-up (all, $P < .01$; Figure 11.3). However, peak activity in the mid-trapezius and lower trapezius was significantly lower in the rope climbing task ($P < .01$).

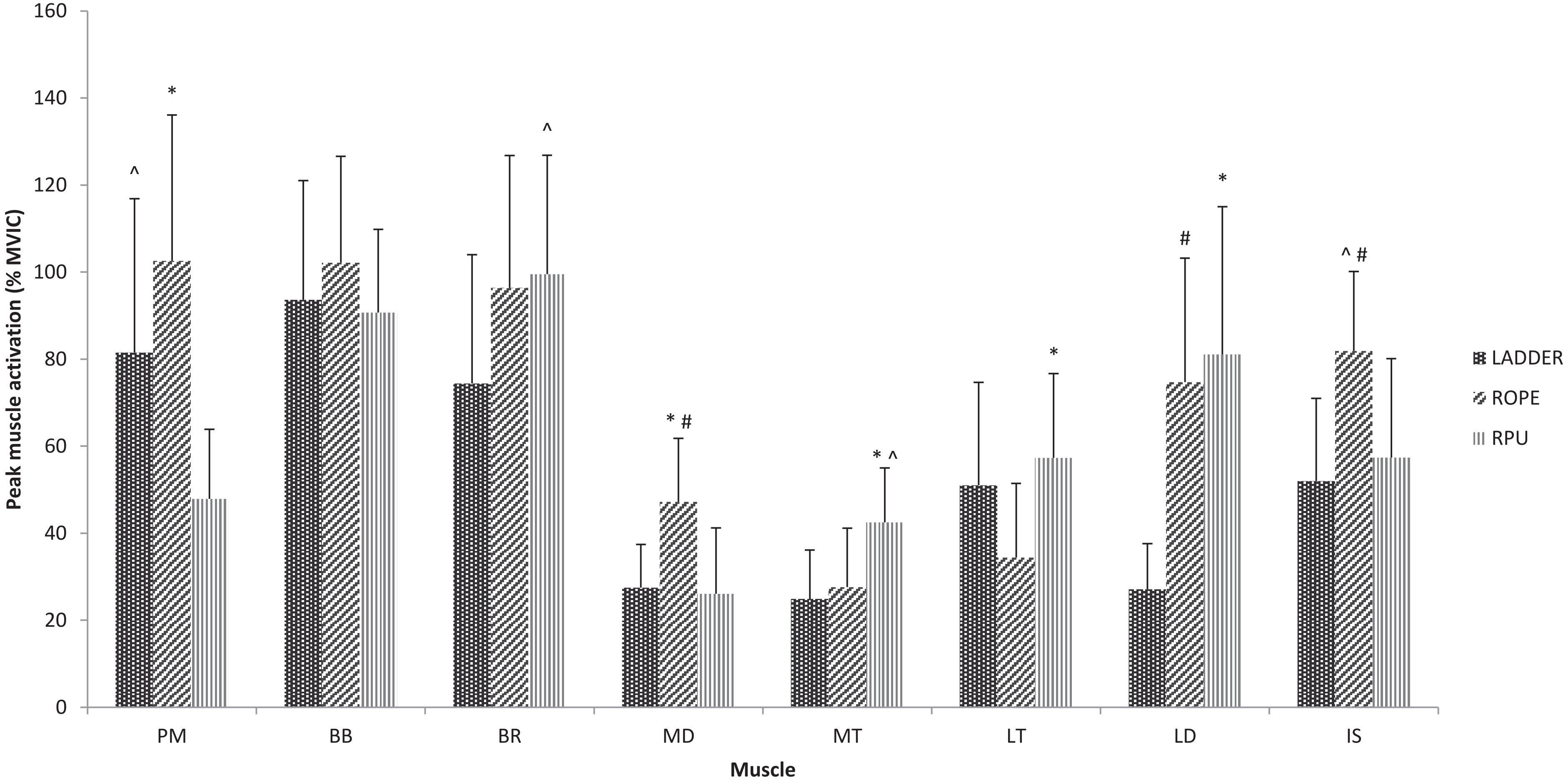

Figure 11.3. Level of peak muscle activity (expressed as %MVIC) during the ladder climb, rope climb and rope pull-up. MVIC = maximal voluntary isometric contraction; ladder = ladder climb; rope = rope climb; RPU = rope pull-up; PM = upper pectoralis major; BB = biceps brachii; BR = brachioradialis; MD = mid-deltoid; MT = middle trapezius; LT = lower trapezius; LD = latissimus dorsi; IS = infraspinatus.

*Significantly greater peak activation between rope climb and rope-pull up ($P < .05$).

^ Significantly greater peak activation between ladder climb and rope-pull up ($P < .05$).

Significantly greater peak activation between ladder climb and rope climb ($P < .05$).

11.1.4. Comparing ladder climb and rope climb

The rope climb elicited significantly greater activation of the mid-deltoid, latissimus dorsi and infraspinatus in comparison to the ladder climb (all, $P = < .01$; Figure 11.3). There were no significant differences observed in the pectoralis major, biceps brachii, brachioradialis, mid-trapezius and lower trapezius (all, $P > .05$).

11.2. Bridge test

11.2.1. Twelve minute bridge correlations

There were no differences in the amount of fatigue experienced during the 12 minute bridge test and each regional STG location. There was a relationship between height and level of fatigue experienced in the internal oblique during the prone position, where more fatigue is experienced by taller people ($r= -.528$, $P < .05$). Greater fatigue was also experienced by the heavier members of the STG for particular muscles including the internal oblique, ($r = -.591$), latissimus dorsi ($r = -.519$) and mid-deltoid ($r = -.578$; all, $P = < .05$) while in the prone position.

11.2.2. Muscle activity during the twelve minute bridge

As shown in Figure 11.4, average muscle activity for every muscle across the duration of the 12 minute bridge was significantly different between prone, dominant side and non-dominant side positions (all, $P < .01$); with exception of the internal oblique during prone and dominant side positions, and latissimus dorsi during dominant and non-dominant side positions (both, $P > .05$). From the three different positions in the bridge test, the prone position produced highest muscle activation in the rectus abdominis, internal oblique and latissimus dorsi; while the dominant side bridge position resulted in highest muscle activation in the external oblique, multifidus, lumbar erector spinae, thoracic erector spinae and mid-deltoid.

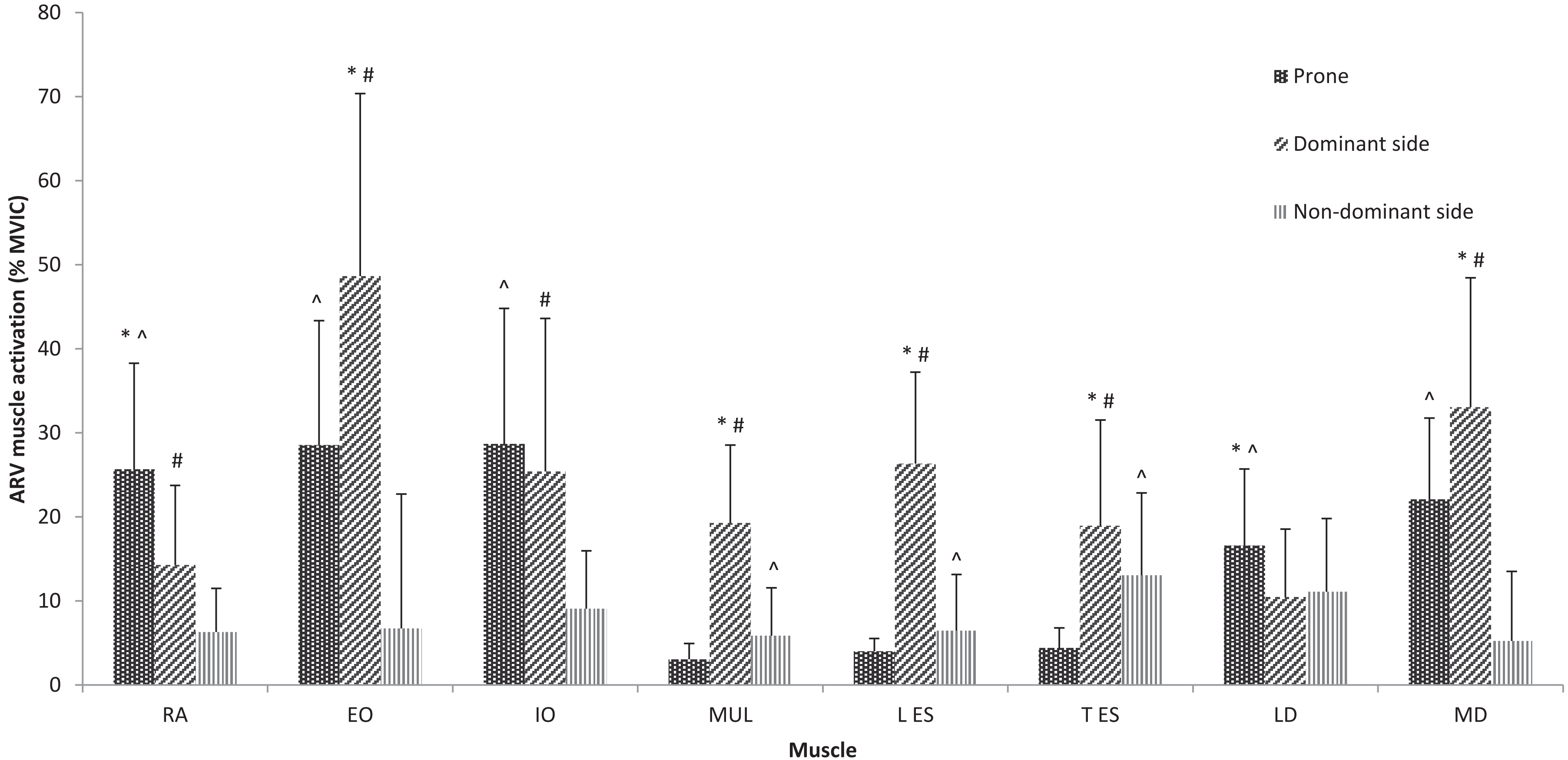

Figure 11.4. Level of ARV muscle activity (expressed as %MVIC) during the 12 minute bridge test performed in prone, dominant-hand side and non-dominant hand side bridge positions. ARV = average rectified variable; MVIC = maximal voluntary isometric contraction; RA = rectus abdominis; EO = external oblique; IO = internal oblique; MUL = multifidus; L ES = lumbar erector spinae; T ES = thoracic erector spinae; LD = latissimus dorsi; MD = mid-deltoid.

*Significantly greater ARV activation between prone and dominant side ($P < .05$).
^ Significantly greater ARV activation between prone and non-dominant side ($P < .05$).
# Significantly greater ARV activation between dominant side and non-dominant side ($P < .05$).

11.2.3. Muscle activity during prone position

Figure 11.5 shows that over the duration of the 12 minute bridge test, muscle activation in the rectus abdominis, external oblique and internal oblique increased in activation from 16, 22 and 16 %MVIC, to values of 36, 39 and 39 %MVIC, respectively. ANOVA demonstrated that amplitude of the rectus abdominis in the final stage of prone position was significantly higher than stages one, two (both, $P < .01$), three, four and five (all, $P < .05$). For the external oblique, stage 12 was significantly higher than stage one ($P < .05$); and for the internal oblique, stage 12 was significantly higher than stages one, two and three (all, $P < .05$). Activity in the lumbar erector spinae also produced significantly higher activation during stage 12 compared to stage one ($P < .05$). There were no significant differences in muscle activation in the multifidus, thoracic erector spinae, latissimus dorsi or mid-deltoid (all, $P > .05$).

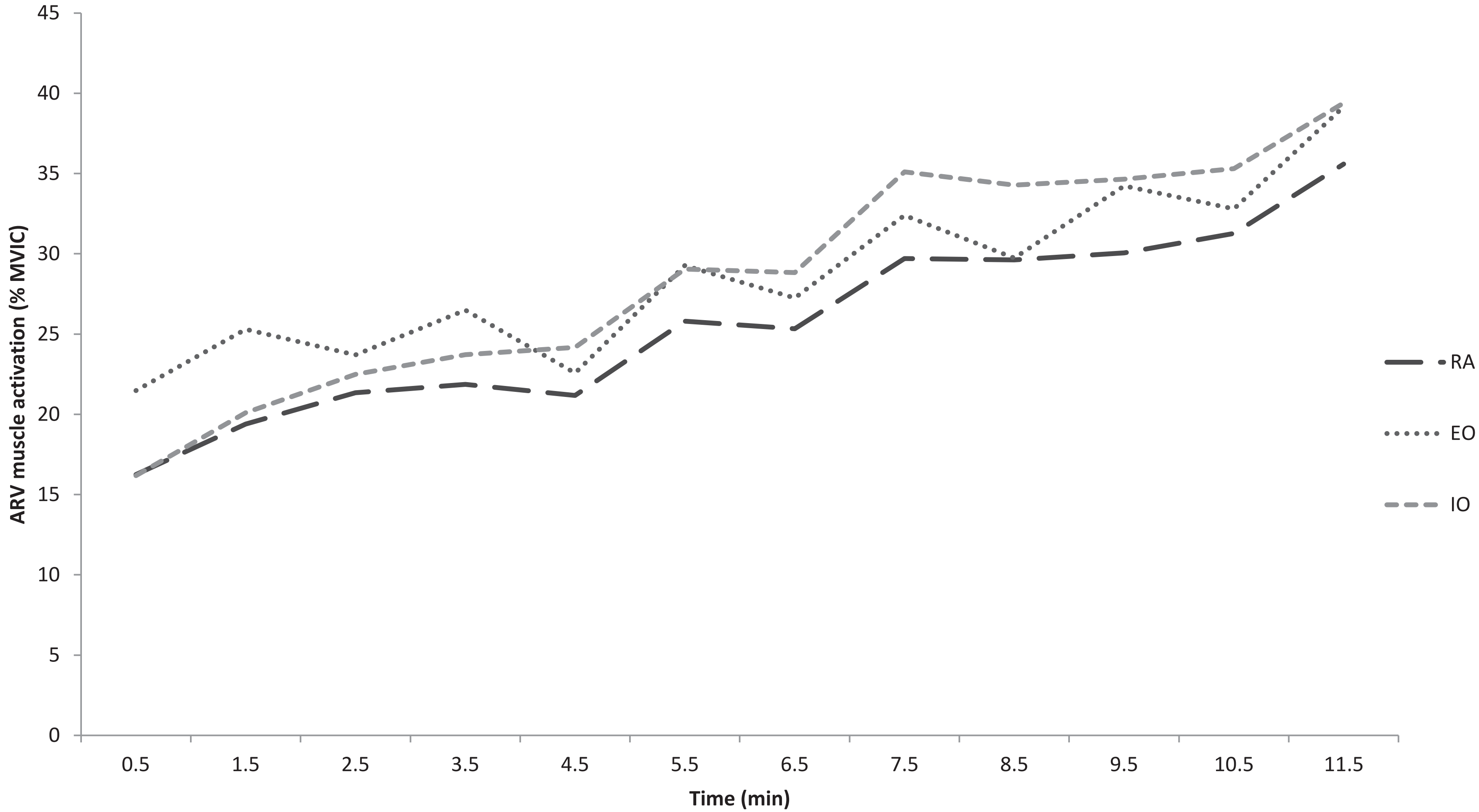

Figure 11.5. Level of ARV muscle activity (expressed as %MVIC) during each stage of the 12 minute bridge test performed in the prone position. ARV = average rectified variable; MVIC = maximal voluntary isometric contraction; RA = rectus abdominis; EO = external oblique; IO = internal oblique.

11.2.4. Muscle activity during dominant side position

All muscles on the same side as the brace arm (dominant side) during the side bridge position, displayed a small increase in activation across the duration of the test, with exception of the external oblique (Table 11.1). The ANOVA revealed significantly greater muscle activation of the external oblique between the first and last stage of the test ($P < .05$), with an increase from 37 to 58.8 %MVIC.

Table 11.1. Normalised ARV EMG obtained during the side bridge performed on the dominant [electrode] side (%MVIC).

Time (min)	RA	(SD)	EO	(SD)	IO	(SD)	MUL	(SD)	LES	(SD)	TES	(SD)	LD	(SD)	MD	(SD)
1	10.8	5.7	37.0	9.3	16.9	11.8	16.6	8.7	24.3	12.7	15.3	10.1	8.4	6.0	35.2	17.9
3	12.4	10.0	42.4	16.1	21.5	15.5	17.7	8.9	26.0	11.3	16.6	11.6	9.8	7.3	31.4	14.6
5	13.8	9.3	48.4	17.8	26.1	19.4	20.1	10.0	26.5	11.3	19.4	14.2	11.0	9.6	32.4	15.4
7	15.7	10.0	55.2	25.7	27.4	18.0	19.4	9.6	26.6	11.3	18.6	11.0	10.5	8.1	32.1	16.0
9	15.3	10.0	50.2	19.6	29.1	20.3	20.7	9.6	26.9	9.9	21.7	13.9	11.4	9.5	32.8	13.6
11	17.5	11.1	58.8	30.2	31.6	20.9	21.2	9.3	27.7	10.2	22.2	14.7	11.7	8.5	34.5	16.5

RA = rectus abdominis; EO = external oblique; IO = internal oblique; MUL = multifidus; LES = lumbar erector spinae; TES = thoracic erector spinae; LD = latissimus dorsi; MD = mid-deltoid.

11.2.5. Muscle activity during non-dominant side position

Muscle activation remained relatively constant in all muscles on the opposite side to the brace arm (non-dominant side) during the side bridge position (Table 11.2). There were no significant changes in amplitude across the duration of the test ($P > .05$).

11.2.6. Signal frequency during twelve minute bridge

As detailed in tables 11.3 and 11.4, ANOVA revealed the change in signal frequency across each stage, for all muscles was non-significant during prone and side bridge positions ($P > .05$).

Table 11.2. Normalised ARV EMG obtained during the side bridge position performed on the non-dominant [non-electrode] side (%MVIC).

Time (min)	RA	(SD)	EO	(SD)	IO	(SD)	MUL	(SD)	LES	(SD)	TES	(SD)	LD	(SD)	MD	(SD)
2	4.8	3.6	4.6	9.4	6.5	5.4	4.9	4.1	5.9	6.4	11.2	8.0	9.4	6.6	4.5	7.0
4	5.9	4.9	5.1	10.7	7.4	6.1	5.2	4.4	6.2	6.8	12.9	9.2	11.5	9.6	3.7	6.4
6	6.0	5.1	7.2	18.6	8.7	6.3	5.6	4.5	6.4	6.7	12.6	9.5	11.4	9.6	4.7	7.1
8	6.7	5.9	7.4	18.9	9.2	7.5	6.0	5.8	6.2	6.3	12.4	9.3	11.1	8.1	5.5	8.9
10	6.6	5.5	7.0	15.4	10.2	7.4	6.5	7.7	6.5	7.1	13.9	11.1	10.9	8.9	6.4	9.6
12	7.6	6.1	9.0	21.3	12.2	7.8	7.0	7.1	7.5	7.8	15.3	12.0	12.2	9.9	6.7	10.7

RA = rectus abdominis; EO = external oblique; IO = internal oblique; MUL = multifidus; LES = lumbar erector spinae; TES = thoracic erector spinae; LD = latissimus dorsi; MD = mid-deltoid

Table 11.3. Median frequency during each stage of the prone bridge (Hz).

Time (min)	RA	(SD)	EO	(SD)	IO	(SD)	MUL	(SD)	L ES	(SD)	T ES	(SD)	LD	(SD)	MD	(SD)
0.5	60.1	10.0	43.7	10.3	37.4	3.8	32.1	15.1	25.8	6.6	28.0	12.8	54.2	19.9	73.5	9.7
1.5	57.6	9.3	40.8	7.9	35.5	4.2	28.9	14.1	26.9	7.1	29.9	11.3	50.4	16.9	67.7	7.9
2.5	54.4	9.8	39.2	5.7	34.7	3.4	28.0	13.3	25.8	6.3	31.1	13.0	49.3	18.6	68.4	9.7
3.5	53.8	9.0	37.9	7.2	32.8	3.9	26.2	11.2	25.6	6.7	30.7	9.1	49.2	18.3	65.7	10.3
4.5	55.1	10.0	39.0	6.8	33.6	5.1	26.0	11.5	26.9	5.6	31.2	14.6	48.1	17.9	66.2	8.0
5.5	52.2	8.9	38.5	7.1	33.1	4.5	28.2	12.2	27.1	7.7	29.1	9.4	48.1	15.2	63.9	8.9
6.5	53.6	11.1	37.5	5.6	33.5	5.0	26.4	11.8	27.7	8.0	30.2	12.3	47.1	15.2	67.1	9.8
7.5	50.7	10.7	37.9	10.0	33.1	4.4	27.0	12.1	25.6	8.1	27.0	9.6	47.4	15.6	64.4	10.9
8.5	49.9	9.9	38.1	8.1	33.3	5.6	27.5	11.2	28.2	8.1	31.2	10.9	48.5	15.1	65.5	10.3
9.5	51.7	9.4	38.2	8.7	32.8	4.8	25.0	12.1	26.0	6.9	30.0	11.6	46.2	14.3	64.6	12.3
10.5	49.6	10.6	36.9	6.7	33.8	4.9	27.5	12.4	28.6	6.9	33.6	11.5	50.4	16.6	66.6	12.1
11.5	48.6	11.6	38.5	8.5	32.9	3.8	28.6	12.3	26.9	6.5	28.7	10.0	44.3	13.1	65.0	12.0

RA = rectus abdominis; EO = external oblique; IO = internal oblique; MUL = multifidus; L ES = lumbar erector spinae; T ES = thoracic erector spinae; LD = latissimus dorsi; MD = mid-deltoid.

Table 11.4. Median frequency during each stage of the side bridge performed on the dominant [electrode] side (Hz).

Time (min)	**RA**	**(SD)**	**EO**	**(SD)**	**IO**	**(SD)**	**MUL**	**(SD)**	**L ES**	**(SD)**	**T ES**	**(SD)**	**LD**	**(SD)**	**MD**	**(SD)**
1	42.7	11.7	39.0	5.2	50.0	21.0	69.2	14.1	57.1	17.1	44.5	13.9	39.6	15.4	82.0	14.2
3	38.5	12.4	38.4	4.5	57.6	25.7	68.6	25.7	60.1	15.5	46.1	14.0	39.8	14.4	75.5	16.6
5	40.0	13.0	39.8	6.3	57.9	19.6	71.6	16.7	61.2	16.5	47.4	13.3	41.6	16.0	76.1	12.5
7	41.8	13.8	37.3	5.7	59.5	29.6	66.8	15.9	61.9	18.4	46.6	12.5	41.6	14.2	76.2	14.3
9	39.4	12.2	37.0	6.4	62.0	33.3	72.2	16.7	60.4	18.8	48.5	11.9	41.4	12.1	73.9	13.8
11	40.0	12.3	36.1	6.4	61.5	25.3	71.3	16.1	62.3	17.5	48.2	11.2	43.8	11.2	76.3	15.9

RA = rectus abdominis; EO = external oblique; IO = internal oblique; MUL = multifidus; L ES = lumbar erector spinae; T ES = thoracic erector spinae; LD = latissimus dorsi; MD = mid-deltoid.

12. DISCUSSION

12.1. Rope pull-ups

The primary purpose of this research was to identify whether the rope pull-up is a suitable assessment tool to evaluate operational climbing ability. It was shown that neither arm limb length, nor height, was an advantage or disadvantage in rope pull-up ability. Results indicate that the rope pull-up is not a suitable assessment of either rope climb or the ladder climb ability; however, the rope climb serves as a good assessment of ladder climb ability.

12.1.1. Anthropometric variables

Our results showed that neither height, nor arm-length influenced the amount of rope pull-ups completed. However, strong negative correlations were observed between body mass and BMI and the ability to perform the pull-up task. As BMI is calculated from body mass and height, it is commonly used as a measure of body composition (Flegal et al., 2009). The underlying assumption with BMI is that for a given height, increased body mass represents increased levels of body fat (Flegal et al., 2009). Hence, those with larger fat mass can perform fewer pull-ups. In support of our observed correlations, research performed by Vanderburgh and Edmonds (1997) investigated the effect of fat mass on pull-up ability. The total mass of an individual was manipulated by adding known weight, and having the participants perform a max repetition set of pull-ups. Using allometric scaling the authors reported that a 10 % increase in total mass lifted resulted in a 53 % reduction in pull-up ability (Vanderburgh & Edmonds, 1997).

12.1.2. Muscle activation

Important to this research, positioning of the forearm dictates the primary elbow flexor involved with the movement. When performing a pull-up with a supinated grip (chin-up) the orientation of the forearm inferred that the biceps brachii would have greatest muscle activation, whereas a pronated grip requires increased brachialis activation, and neutral grip requiring greater brachioradialis activation (Floyd, 2012; Ronai & Scibek, 2014). Although the difference was non-significant, the neutral position of the rope pull-up, as expected, elicited 8.8 % greater activation of the brachioradialis in comparison to the biceps brachii.

The upper pectoralis major is an important internal rotator of the arm, providing an essential action to maintain position on a rope or ladder whilst performing climbing tasks (Floyd, 2012). The rope pull-up only resulted in 47.9 %MVIC muscle activation whereas very high pectoralis major activation of 81.5 and 102.6 %MVIC occurred during the ladder and rope climb, respectively. These results indicate that the rope pull-up is unable to activate the pectoralis major to a similar degree required in operational climbing tasks. Due to the action of the pectoralis major, this could result in inadequate ability to maintain position on operational climbing apparatuses when the rope pull-up is used to assess climbing ability.

12.1.2a. Comparing ladder climb and rope pull-up

Muscle activity in the brachioradialis, mid-trapezius and latissimus dorsi was significantly greater during the rope pull-up compared to the ladder climb. To our knowledge, there is no published data assessing brachioradialis or mid-trapezius during pull-up tasks; although higher muscle activity of the latissimus dorsi (117 %MVIC) was reported by Youdas et al. (2010) during a conventional pull-up. Greater activity of the brachioradialis during the rope pull-up was expected due to the neutral hand position as opposed to a supinated grip when climbing the ladder. Likewise, higher muscle activation in the mid-trapezius and latissimus dorsi is likely due to the shoulder and scapular undergoing greater extension and adduction, respectively, at the top of the rope pull-up when compared to the presumed more discrete actions of the ladder climbing cycles. Furthermore, the rope pull-up required the participant to overcome their entire body weight resistance, thus requiring greater muscle activation to generate more force from the main muscles. In contrast, when climbing the ladder with proper technique, one foot maintains contact with the apparatus at all times. Some of the upward propulsive force is likely generated from the lower limbs, possibly explaining the lower observed activation of the aforementioned muscles.

12.1.2b. Comparing rope climb and rope pull-up

Muscle activation of the mid-deltoid and infraspinatus was significantly greater during the rope climb compared to the rope pull-up. Of all three tasks, the rope climb required participants to abduct their shoulder to the greatest extent; of which the mid-deltoid is the major muscle involved (Floyd, 2012). However, the role of the mid-deltoid during all three tasks is still considered minimal, with the highest peak activation only reaching 47.2 %MVIC during the rope climb. Potentially, a more important portion of the deltoid muscle to analyse would have been the posterior fibres due to their role in extension of the glenohumeral joint (Floyd, 2012; Ronai & Scibek, 2014; Youdas et al., 2010). The lower infraspinatus activity during the rope pull-up may result from the task being bi-lateral; therefore, less activation is required because the load was being shared relatively evenly across both sides of the body. Whereas the uni-lateral rope climb requires greater muscle activity as the arm/shoulder is working alone. Importantly, uni-lateral activities require greater activation to provide extra stability to the joint (Behm, Leonard, Young, Bonsey, & MacKinnon, 2005). Unlike the ladder climb, similar activation of all other muscles (with exception of pectoralis major) was likely caused by the propulsive phase of the ladder climb requiring participants to overcome their full body weight resistance, much the same as the rope pull-up.

12.1.2c. Comparing ladder climb and rope climb

As a consequence of major differences in movement patterns between the rope pull-up and operational climbing tasks (i.e. uni-lateral versus bi-lateral phases), muscle activity between the two uni-lateral climbing tasks was compared. Analysis revealed that all muscles were either similar or significantly higher during the rope climbing task compared to the ladder climb. The observed higher activation of the mid-deltoid may be explained by the rope climbing phases requiring abduction of the shoulder, whereas the hand positioning during the ladder climb resulted in shoulder flexion where the anterior deltoid fibres are the prime movers (Floyd, 2012). The higher muscle activation of the latissimus dorsi is explained by its major role in internal rotation of the glenohumeral joint (Floyd, 2012; Pink, Jobe, & Perry, 1990). Due to the instability of the rope climb, and neutral hand positioning, there is enhanced reliance on internal rotation of the shoulder to maintain position on the rope. This is also reflected in the 21.1 % greater activation of the pectoralis major to keep the rope and arm close to the body during the rope climb compared to the ladder climb. Similarly, the higher activation of the infraspinatus is attributed to greater instability of the rope climbing apparatus compared with the ships ladder.

The rope pull-up and other pull-up exercises serve as good ‘field based’ assessments of muscular strength and endurance in multiple muscles, including the: biceps brachii; brachioradialis; lower trapezius; latissimus dorsi; and infraspinatus (Lehman et al., 2004; Lusk et al., 2010; Ricci et al., 1988; Youdas et al., 2010). However, due to insufficient activation of the pectoralis major and infraspinatus during the rope pull-up compared to the ladder climb and rope climb tasks, it may be inferred that the rope pull-up does not simulate operational climbing tasks. Although the rope pull-up was deemed not suitable to assess one’s ability to perform operational climbing tasks; the rope climb served as a good assessment of ladder climb ability, as all muscles were activated to a similar extent or higher during that task. Hence, the NZ Police may wish to substitute the rope pull-up with the rope climb to be more in-line with assessment of job tasks.

12.2. Bridge test

The purpose of the second part to Phase Two of this research was to identify whether the 12 minute bridge test is a suitable assessment of core endurance; and whether the duration of the test is likely to cause injury. The 12 minute bridge test serves as a good assessment of core endurance of all major core stabilisers as the rotation allows assessment of the posterior core muscles (side position), and anterior core muscles (prone position). Furthermore, results indicate that muscle fatigue was minimal due to no significant changes in EMG signal frequency across all stages of the test, in all positions.

12.2.1. Muscle activation

The analysis of ARV EMG data provided information about the degree of muscle activation associated with each specific phase of the bridge test, and over the duration of the test. From the three different positions in the bridge test, the prone position produced highest ARV activation in the rectus abdominis, internal oblique and latissimus dorsi; with averaged values over the duration of the test of 25.7, 28.7 and 16.6 %MVIC, respectively. While the main action of the rectus abdominis is lumbar flexion and posterior pelvic tilt, the insertion onto the cartilage of the 5th, 6th, and 7th ribs and xyphoid process means that contraction of this muscle acts on the spinal column to produce stability (Anderson & Behm, 2005; Floyd, 2012; McGill, Andersen, & Cannon, 2014). The observed activation of the rectus abdominis was similar to that previously reported for the prone bridge position (Garcia-Vaquero et al., 2012; Lehman et al., 2005; Tong et al., 2013). However, higher values have also been reported (Ekstrom et al., 2007; Schellenberg et al., 2007).

Contraction of the internal oblique causes lumbar flexion, lateral flexion and rotation, and posterior pelvic rotation (Floyd, 2012). Similar to the rectus abdominis, the insertion of the internal oblique is the rib cage. Therefore, contraction of the muscle acts to prevent unwanted trunk movement and to assist with stability during directional and weight bearing activity (Barr et al., 2005). The present study’s observed muscle activity of 29 %MVIC was similar to the 30 %MVIC reported by Lehman et al. (2005), although lower values (16 %MVIC) have also been reported (Garcia-Vaquero et al., 2012). Conversely, during the side bridge position the observed internal oblique muscle activation (25 %MVIC) was 11-33 %MVIC lower than all other previously reported values (Hibbs et al., 2011; Juker et al., 1998; Lehman et al., 2005; Youdas et al., 2008). Interestingly, one study examined the internal oblique during both the prone and side bridge positions (Lehman et al., 2005). Contrary to our results, Lehman et al. (2005) reported highest muscle activity during the side bridge compared to the prone bridge (43 & 30 %MVIC, respectively).

The final muscle that elicited highest activation during the prone position was the latissimus dorsi. Although not directly involved in movement of the spine, the latissimus dorsi has been shown to influence spinal stability due to its anatomical origin from the posterior crest of the ilium, posterior aspect of the sacrum, and spinous processes of the lumbar and lower thoracic spine (Vleeming, Poolgoudzwaard, Stoeckart, Vanwingerden, & Snijders, 1995). Our results indicated that the highest observed activity of the latissimus dorsi (17 %MVIC) was still only considered low based on previous classifications (Digiovine et al., 1992). Stabilisation of the spine by the latissimus dorsi occurs via the thoracolumbar fascia, which is increasingly required during directional movements (Barr et al., 2005). Hence, low activation of the latissimus dorsi during bridging exercises may be due to the isometric position analysed during the test. However, it was speculated that the latissimus dorsi would acquire a more important role in core stabilisation when moving from prone to the side bridge, or vice versa.

During the side bridge position greatest activation occurred in all muscles on the ipsilateral side to the brace arm. This position elicited highest muscle activation in the external oblique, multifidus, lumbar erector spinae, thoracic erector spinae and mid-deltoid. Similar to other anterior core muscles, the external oblique acts as a spinal stabiliser due to its origin from the ribs, and insertion onto the pelvis (Floyd, 2012). The observed muscle activity of 49 %MVIC was the highest mean ARV activation of all muscles, across the duration of the test. Similar muscle activation ranging from 43-51 %MVIC has been previously reported in the side position (Juker et al., 1998; Lehman et al., 2005; Youdas et al., 2008). However, higher (Ekstrom et al., 2007; Hibbs et al., 2011; Marshall et al., 2011); and lower (Garcia-Vaquero et al., 2012) values have also been reported. Due to the relatively high activation of the external oblique during the side bridge, it has been recommended that individuals wishing to improve endurance of the external oblique utilise this exercise (McGill, 2001).

The multifidi appear to have a major role in assisting with spine orientation as they are among the first muscles to become active when a limb is moved in repose to a visual stimulus (Barr et al., 2005; Moseley, Hodges, & Gandevia, 2002). The observed activity of 19 %MVIC during the side bridge was lower than that previously reported (Ekstrom et al., 2007; Hibbs et al., 2011). Ekstrom et al. (2007) maintain that the multifidus can be accurately monitored with surface EMG. However, research utilisng intramuscular electrodes and surface electrodes inferred that the crosstalk from adjacent muscles makes surface electrodes in-accurate when monitoring deep muscles of the torso (Stokes, Henry, & Single, 2003). Importantly, the multifidi consists of both deep and superficial fibres with the fibres providing most stabiliasation also being the deepest (Barr et al., 2005). This could potenially cause flawed results when attempting to measure multifidi muscle activity using surfae EMG, and may explain our observed differences (Barr et al., 2005).

Those with weaker spine extensor muscles have been shown to display lower muscular endurance, causing difficulty performing ADL and load carriage tasks (Ebenbichler, Oddsson, Kollmitzer, & Erim, 2001; Moseley et al., 2002). The spine extensors have been identified as extremely important in preventing low back pain (Barr et al., 2005); as such, the side bridge is commonly used in rehabilitation settings to improve muscular strength and endurance of the erector spinae muscle group (Garcia-Vaquero et al., 2012; Marshall et al., 2011). The lumbar and thoracic regions of the erector spinae on the ipsilateral side to the brace arm experienced activation of 26 and 19 %MVIC, respectively. This activation was similar to previous research (Garcia-Vaquero et al., 2012; Juker et al., 1998; Lehman et al., 2005); however, higher values have also been reported (Ekstrom et al., 2007; Hibbs et al., 2011; Marshall et al., 2011). Importantly, activation of all muscles on the contralateral side to the brace arm was below 14 %MVIC, and considered low.

The final muscle analysed during the bridge task was the mid-deltoid. Although this muscle is not directly involved in core stability, discussions with STG members who have performed the 12 minute bridge test made comment that they felt their shoulders were working harder than their core. As the deltoid abducts the arm, it was postulated that the brace position associated with bridging may place a large degree of stress on the deltoid muscle. According to previous classifications of muscle activity, our results indicated that the deltoid was moderately active whilst prone and in the dominant side position; but low when the contralateral arm was used to brace.

The level of normalised muscle activity during each stage of the 12 minute bridge test was also analysed. The use of rotations means each participant performed a total of 12 x 30 second bridges in the prone position, six x 30 second bridges on their dominant hand side, and six x 30 second bridges on their non-dominant hand side. Throughout the prone positions, muscle activity of the rectus abdominis was significantly higher in the final stage compared to stages one to five. Similarly, the final stage was significantly higher than stages one to three for the internal oblique, and higher than stage one for the external oblique. Although a significant increase in muscle activity of 19.4, 23.2 and 17.7 %MVIC was observed in the rectus abdominis, external oblique and internal oblique from start to finish of the test; muscle activity was still only considered moderate (20-40 %MVIC) based on previous classifications (Digiovine et al., 1992).

Not surprisingly, the three most activated muscles during the prone position were also the three that experienced the greatest increase in muscle activation over the duration of the test. It is important to note that increases in EMG signal amplitude for the same force development throughout the test indicates that fatigue may be occurring. All muscles on the same side as the brace arm (dominant side) during the side bridge position, displayed only a slight increase in activation across the duration of the test, with exception of the external oblique which increased by 22 %MVIC. Meaning that while in the dominant side, there are no significantly greater demands for muscle activation over the duration of the test, with the exception of the external oblique.

Finally, muscle activation remained consistently low in all muscles on the opposite side to the brace arm (non-dominant side) during the side bridge position.

12.2.2. Signal frequency

To our knowledge this is the first study to examine muscular fatigue over a 12 minute rotational bridge. Although taller and heavier individuals experienced a greater fatigue index in particular muscles, this would likely represent a smaller relative stress for them during operational tasks such as load carriage. Results showed no significant changes in EMG signal frequency across all stages of the test, in all positions. This means the firing rate of action potentials was not significantly influenced by muscular fatigue. Muscle fatigue generally results from prolonged, relatively strong muscle activity, causing a reduced ability to produce force (Giannesini, Cozzone, & Bendahan, 2003; Kumar et al., 2003). The resulting metabolite accumulation decreases membrane excitability, and essentially motor unit firing frequency; thus causing a shift toward lower EMG frequencies (Allen, 2004; Zwarts et al., 2008).

To counteract the reduction in firing frequency, there is an increase in EMG muscle activity (amplitude) (Medved & Cifrek, 2011; Zwarts et al., 2008). Although no previous research has analysed fatigue at different stages during isometric positions of a rotational bridge, the observed increase in muscle activation was expected based on previous fatigue studies (Barnes, 1980; Kumar et al., 2003; Yoshitake et al., 2001). However, our results demonstrated no significant changes in EMG signal frequency across all stages of the test, in all positions. Thus indicating that muscular fatigue was minimal, and therefore the chance of fatigue related injury during the bridge test was low.

The reason fatigue was minimal is likely attributed to the changes in position throughout the test. When a participant was performing the side bridge on their non-dominant arm, the measured muscle activity on the dominant side of the body was < 15 % of the maximum they could produce in all measured muscles. Muscles become ischemic with sustained contractions exceeding 20 %MVIC (Barnes, 1980; Yoshitake et al., 2001). Hence, the low activation of all muscles in the contralateral side to the brace arm allows blood to flow into the muscle, reducing the build-up of fatigue causing metabolites from the previous bridge position. When in the prone position the activity of the multifidus and erector spinaes was low, thus allowing them to recover; and likewise for the rectus abdominis when in the dominant side position.

This raises the question, if the 12 minute bridge test does not result in significant fatigue of the core stabilisers then is this test a valid assessment of core endurance? There is no dispute that core endurance is an essential physical trait for STG operators to possess; but to validate the 12 minute bridge test directly to operational requirements it is necessary to research core muscle activity during tasks such as prolonged pack marching. Currently, as there is absence of a single test that suitably engages all major core stabilisers; we believe that the 12 minute bridge test is a suitable assessment of core endurance.

Previous research advises that muscle activity less than 40 %MVIC is optimal when training for muscle endurance (Baker & Newton, 2004; Escamilla et al., 2010; Youdas et al., 2010). Based on our results it appears that bridging exercises are appropriate to assess core endurance. However, it is important to note that the 12 minute bridge should be used as a test, and not relied upon as a training method. This is because core stability encompasses a combination of muscular strength and muscular endurance, in addition to a variety of muscles involved with stabilisation (Bliss & Teeple, 2005).

Core stability should be trained with a variety of endurance and strength based activities to condition the core prior to performing the bridge test, training should include a combination of dynamic, static, multi-planar and balance exercises to target all contributing physical attributes of core stability (Bliss & Teeple, 2005).

12.3. Strengths and limitations

Manual muscle testing has been validated as a normalisation technique, with small variability (15 %MVIC) between measurements accepted (Bolgla & Uhl, 2005; Ekstrom et al., 2005; Hibbs et al., 2011). However, the method employed to obtain MVIC is likely one of the major factors associated with differences in muscle activity between studies when similar electrode placement was used. Manual muscle testing techniques, involving the experimenter providing manual resistance against a participant performing maximal contraction, were used in all but one study (Lehman et al., 2005). Notably, the MVIC can be easily influenced by the exercise chosen, experience of the individual providing manual resistance, and the ability to produce maximal force; thus impacting on the normalised data (Ekstrom et al., 2005; Hibbs et al., 2011).

The aforementioned studies utilised different protocols to obtain MVIC, making comparisons between studies difficult. Tong et al. (2013) and Youdas et al. (2008) only performed one set for each exercise which may present unreliable data in reference to MVIC; however, the employed isometric hold time of five seconds was perceived as optimal to ensure maximum force was produced. Conversely, Ekstrom et al. (2005) performed three sets with an isometric hold of five seconds, but the short rest period of 30s between sets may result in accumulative muscle fatigue, thus decreasing maximal force production in subsequent trials. Set guidelines to obtain MVIC need to be employed to reduce variability in MVIC testing techniques between studies. Based on previous literature we determined that our employed method of familiarisation, followed by 3 sets per exercise, held for five seconds with one minute rest was optimal to ensure MVIC was obtained (Ekstrom et al., 2005; Tong et al., 2013; Youdas et al., 2008).

With surface EMG there is always the possibility for skin artefact and muscle crosstalk. Skin artefact was minimised by rigorous skin preparation methods prior to electrode placement. Tape was also used to prevent the electrode sensor from moving on the skin surface. Finally, the use of a wireless EMG system minimised movement artefact. Correct electrode placement is critical to ensure muscle crosstalk is minimised, ensuring that EMG signal is representative of the targeted muscle. Muscle crosstalk was minimised by using electrode placement recommendations from the reputable SENIAM guidelines, where possible (Merletti & Hermens, 2000). Where SENIAM recommendations were not available for electrode placement, previous research was synthesised to inform the most appropriate electrode positioning (refer Appendix K & L). The multifidus and internal oblique are particularly hard to measure with surface EMG due to the deep orientation of the muscles. Although appropriate steps were taken to ensure appropriate electrode placement was used for these two muscles, it is acknowledged that some muscle crosstalk may have occurred, resulting in atypical EMG recordings. Finally, considering the movement of skin with different hand orientations during the climbing tasks, pilot work was performed by the researches to ensure optimal electrode positioning for the brachioradialis. Hence, the electrode placement for the brachioradialis was not previously referenced.

12.4. Practical applications

Pull-up exercises are commonly used to train muscles of the arm, shoulder girdle and upper back which are commonly used in everyday pulling motions. The rope pull-up elicited activation > 50 %MVIC in the biceps brachii, brachioradialis, lower trapezius, latissimus dorsi and infraspinatus muscles, which is deemed suitable to promote muscular adaptation of the aforementioned muscles. Many uniformed services require a certain degree of upper body strength and muscular endurance to successfully complete climbing tasks which may be encountered on operational duties. Hence, members of these groups need to maintain the physical fitness required to do so. The pull-up exercise is widely used to assess operational climbing ability, however, this research has shown that even a pull-up performed on an unstable surface (rope pull-up) still does not elicit the muscle activation required to perform operational climbing tasks.

Due to obvious differences in bi-lateral versus uni-lateral phases of the pull-up and climbing tasks, operational climbing ability needs to be assessed with climbing tasks. Specifically for the NZ Police STG, to assess operational climbing ability annually, it is recommended that the rope climb task be added into the STG annual fitness assessment. However, if the rope pull-up is retained as a measure of upper body muscular strength and endurance, the wording in the STG required physical fitness policy should be changed from: *"the rope pull-up test is used to simulate the upper body relative strength required during narrow ladder accents and other general climbing tasks"* (NZ Police, 2011, p. 21); to: *"the rope pull-up test is used to assess upper body muscular strength and endurance"*.

Rotation between prone and side bridge positions during a core endurance test allows for assessment of all major core muscles involved in stability. However, the rotation requires an advanced degree of core stability as abdominal bracing is needed to maintain correct technique whilst rolling into the new positions (McGill, 2001). McGill and Karpowicz (2009) have shown that rolling from a side bridge to a plank and then to a side bridge on the opposite arm significantly challenge the internal and external obliques, rectus abdominis, latissimus dorsi and the erector spinaes. For this reason the rotational bridge may not be suitable for untrained individuals, or individuals lacking core stability. However, in well trained individuals (such as STG members), the rotational bridge serves as a practical core endurance assessment of all major muscles involved in core stability. Furthermore, no significant change in signal frequency indicates this test can be performed for prolonged durations without tendency for core stability to lessen through fatigue. Although, no significant fatigue was shown to manifest throughout the duration of 12 minutes, the length of time an individual is required to perform the rotational bridge test depends on the degree of required core stability. Specifically for the NZ Police STG, the 12 minute bridge test is a safe assessment of core endurance (providing members are well trained) and should be retained as an assessment of core stability.

13. CONCLUSION

Body weight and BMI may influence performance of the rope-pull up task. Results indicated that, those struggling with performing the rope pull-up task should prioritise losing body fat. The rope pull-up serves as a good 'field based' assessment of muscular strength and endurance in the biceps brachii, brachioradialis, lower trapezius, latissimus dorsi and infraspinatus. However, results indicated that the rope-pull up is not suitable to assess one's ability to perform operational climbing tasks. More specifically, being able to perform a rope climb serves as a suitable test to assess suspended caving ladder climbing ability.

Core stability is an important physical trait for uniformed personnel to possess as a stiffer spine is more resilient to buckling; thus, reducing the risk of injury during operational tasks. The 12 minute bridge test serves as a good assessment of core endurance of all major core stabilisers involved. The use of the rotation allows assessment of the posterior core muscles (side position) and anterior core muscles (prone position). Furthermore, our results revealed that muscle fatigue is not significantly different upon termination of the test compared to baseline muscle function. Hence, the associated risk of fatigue related muscle injury during the 12 minute bridge is low.

14. FUTURE RESEARCH

To determine whether an alternate pull-up activity may be indicative of operational climbing ability, additional research is required to assess the effect of grip width and orientation on muscle activity. Major muscles identified as important during climbing tasks include the upper pectoralis major, biceps brachii, brachioradialis, infraspinatus, latissimus dorsi and lower trapezius. However, the posterior deltoid and lower fibres of the pectoralis major may also have a crucial role when climbing, and therefore should undergo EMG analysis during operational climbing and pull-up activities.

As there was no discernible change in EMG frequency during the 12 minute bridge test, we recommend that the test be performed to performance failure to verify whether the EMG frequency changed accordingly. To validate the required length of time to perform a rotational bridge test, it is first necessary to determine the level of core endurance required by members of uniformed services. Load carriage tasks are commonly performed among uniformed services, with greater levels of core stability required to overcome the external resistance. To link the use of core endurance tests to required levels of core stability it is necessary to research core muscle activity during operational tasks. Future research should be directed at identifying core muscle activity during commonly performed operational tasks, including prolonged pack marching activities, to justify the required length of time used during core stability assessments.

15. REFERENCES

Abt, J. P., Sell, T. C., Lovalekar, M. T., Keenan, K. A., Bozich, A. J., Morgan, J. S., et al. (2014). Injury epidemiology of US Army Special Operations Forces. *Military medicine, 179*(10), 1106-1112.

ACSM (Ed.). (2010). *ACSM's health-related physical fitness assessment manual* (3rd ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins Health.

Australian Defence Force. (2014). Physical fitness assessment. 2014, from: http://www.defencejobs.gov.au/recruitmentCentre/howToJoin/fitnessTest/

Adrian, E. D., & Bronk, D. W. (1929). The discharge of impulses in motor nerve fibres. Part II. The frequency of discharge in reflex and voluntary contractions. *Journal of Physiology-London, 67*(2), 119-151.

Ahlstrom, P., & Westbrook, R. (1999). Implications of mass customization for operations management - An exploratory survey. *International Journal of Operations & Production Management, 19*(3-4), 262-274.

Akuthota, V., & Nadler, S. F. (2004). Core strengthening. [Review]. *Archives of physical medicine and rehabilitation, 85*(3), S86-92.

Allen, D. G. (2004). Skeletal muscle function: Role of ionic changes in fatigue, damage and disease. *Clinical and Experimental Pharmacology and Physiology, 31*(8), 485-493.

ACSM., Thompson, W. R., Gordon, N. F., & Pescatello, L. S. (Eds.). (2010). *ACSM's guidelines for exercise testing and prescription* (8th ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Andersen, L. L., Magnusson, S. P., Nielsen, M., Haleem, J., Poulsen, K., & Aagaard, P. (2006). Neuromuscular activation in conventional therapeutic exercises and heavy resistance exercises: Implications for rehabilitation. *Physical Therapy, 86*(5), 683-697.

Anderson, G., & Plecas, D. (2007). *Physical abilities requirement evaluation (PARE), phase 1: task analysis*. Abbortsford, BC: University College of the Fraser Valley.

Anderson, G., Plecas, D., & Segger, T. (2001). Police officer physical ability testing - Re-validating a selection criterion. *Policing - an International Journal of Police Strategies & Management, 24*(1), 8-31.

Anderson, G. S., & Plecas, D. B. (2008). *Physical abilities requirement evaluation (PARE), phase 2: discrete item analysis*. Abbortsford, BC: University College of the Fraser Valley.

Anderson, K., & Behm, D. G. (2005). The impact of instability resistance training on balance and stability. *Sports Medicine, 35*(1), 43-53.

Anderson, M., Hopkins, W., Roberts, A., & Pyne, D. (2008). Ability of test measures to predict competitive performance in elite swimmers. *Journal of Sports Sciences, 26*(2), 123-130.

Argus, C. K., Gill, N. D., Keogh, J. W., & Hopkins, W. G. (2014). Assessing the variation in the load that produces maximal upper-body power. *The Journal of Strength & Conditioning Research, 28*(1), 240-244.

Baker, D. G., & Newton, R. U. (2004). An analysis of the ratio and relationship between upper body pressing and pulling strength. *Journal of Strength and Conditioning Research, 18*(3), 594-598.

Barnes, W. S. (1980). The relationship between maximum isometric strength and intramuscular circulatory occlusion. *Ergonomics, 23*(4), 351-357.

Barr, K. P., Griggs, M., & Cadby, T. (2005). Lumbar stabilization - Core concepts and current literature, part 1. *American Journal of Physical Medicine & Rehabilitation, 84*(6), 473-480.

Basmajian, J. V., & De Luca, C. J. (1985). *Muscles alive : their functions revealed by electromyography* (5th ed.). Baltimore: Williams & Wilkins.

Beckett, M. B., Goforth, H. W., & Hodgdon, J. A. (1989). *Physical fitness of US Navy special forces team members and trainees*: DTIC Document.

Behm, D. G., Leonard, A. M., Young, W. B., Bonsey, W. A. C., & MacKinnon, S. N. (2005). Trunk muscle electromyographic activity with unstable and unilateral exercises. *Journal of Strength and Conditioning Research*, *19*(1), 193-201.

Berg, A. M., Hem, E., Lau, B., Haseth, K., & Ekeberg, O. (2005). Stress in the Norwegian Police service. *Occupational Medicine-Oxford, 55*(2), 113-120.

Billat, V. L., Sirvent, P., Py, G., Koralsztein, J. P., & Mercier, J. (2003). The concept of maximal lactate steady state - A bridge between biochemistry, physiology and sport science. *Sports Medicine, 33*(6), 407-426.

Bliss, L. S., & Teeple, P. (2005). Core stability: the centerpiece of any training program. *Curr Sports Med Rep, 4*(3), 179-183.

Bloswick, D., & Chaffin, D. (1990). An ergonomic analysis of the ladder climbing activity. *International Journal of Industrial Ergonomics, 6*, 10.

Bolgla, L. A., & Uhl, T. L. (2005). Electromyographic analysis of hip rehabilitation exercises in a group of healthy subjects. *The Journal of Orthopaedic and Sports Physical Therapy, 35*(8), 487-494.

Bonneau, J., & Brown, J. (1995). Physical ability, fitness and police work. *Journal of Clinical Forensic Medicine, 2*(3), 157-164.

Borghuis, J., Hof, A. L., & Lemmink, K. A. P. M. (2008). The importance of sensory-motor control in providing core stability: implications for measurement and training. *Sports Medicine, 38*(11), 893-916.

Bradley, P. S., & Portas, M. D. (2007). The relationship between preseason range of motion and muscle strain injury in elite soccer players. *Journal of Strength and Conditioning Research, 21*(4), 1155-1159.

Broman, H., De Luca, C. J., & Mambrito, B. (1985). Motor Unit Recruitment and Firing Rates Interaction in the Control of Human Muscles. *Brain Research, 337*(2), 311-319.

Buchheit, M. (2012). Repeated-sprint performance in team sport players: Associations with measures of aerobic fitness, metabolic control and locomotor function. *International Journal of Sports Medicine, 33*(3), 230-239.

Burden, A. M., & Redmond, C. G. (2013). Abdominal and hip flexor muscle activity during 2 minutes of sit-ups and curl-ups. *Journal of Strength and Conditioning Research, 27*(8), 2119-2128.

Burke, E. J. (1976). Validity of selected laboratory and field-tests of physical working capacity. *Research Quarterly, 47*(1), 95-104.

Burke, R. J. (1994). Stressful events, work-family conflict, coping, psychological burnout, and well-being among police officers. *Psychological Reports, 75*(2), 787-800.

Burns, K. E. A., Duffett, M., Kho, M. E., Meade, M. O., Adhikari, N. K. J., Sinuff, T., et al. (2008). A guide for the design and conduct of self-administered surveys of clinicians. *Canadian Medical Association Journal, 179*(3), 245-252.

Cady, E. B., Jones, D. A., Lynn, J., & Newham, D. J. (1989). Changes in force and intracellular metabolites during fatigue of human skeletal-muscle. *Journal of Physiology-London, 418*, 311-325.

Callaghan, J. P., & McGill, S. M. (2001). Intervertebral disc herniation: studies on a porcine model exposed to highly repetitive flexion/extension motion with compressive force. *Clinical biomechanics, 16*(1), 28-37.

Carlson, M. J., & Jaenen, S. P. (2012). The development of a preselection physical fitness training program for Canadian Special Operations Regiment applicants. *Journal of Strength and Conditioning Research,* 26(2), S2-14.

Caterisano, A., Moss, R. F., Pellinger, T. K., Woodruff, K., Lewis, V. C., Booth, W., et al. (2002). The effect of back squat depth on the EMG activity of 4 superficial hip and thigh muscles. *Journal of Strength and Conditioning Research, 16*(3), 428-432.

Christensen, L. B. (2007). *Experimental methodology* (10th ed.). Boston: Pearson/Allyn & Bacon.

Cooper, K. H. (1968). A means of assessing maximal oxygen intake: Correlation between field and treadmill testing. *JAMA: The Journal of the American Medical Association, 203*(3), 201-204.

Cooper, K. H. (1977). *The aerobics way: new data on the world's most popular exercise program*. New York: Lippincott.

Copay, A. G., & Charles, M. T. (1998). Police academy fitness training at the police training institute, University of Illinois. *An Internaional Journal of Police Strategies and Management, 21*(3), 15.

Corbetta, P. (2003). *Social research : theory, methods and techniques*. London: SAGE Publications.

Cowley, P. M., Fitzgerald, S., Sottung, K., & Swensen, T. (2009). Age, weight, and the front abdominal power test as predictors of isokinetic trunk strength and work in young men and women. *Journal of Strength and Conditioning Research, 23*(3), 915-925.

Creswell, J. W. (2002). *Research design : qualitative, quantitative, and mixed methods approaches* (2nd ed.). London: SAGE Publications.

Cuddy, J. S., Slivka, D. S., Hailes, W. S., & Ruby, B. C. (2011). Factors of trainability and predictability associated with military physical fitness test success. *Journal of Strength and Conditioning Research, 25*(12), 3486-3495.

da Silva, J. F., Guglielmo, L. G., & Bishop, D. (2010). Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. *Journal of strength and conditioning research, 24*(8), 2115-2121.

Dadebo, B., White, J., & George, K. P. (2004). A survey of flexibility training protocols and hamstring strains in professional football clubs in England. *British Journal of Sports Medicine, 38*(4), 388-394.

De Luca, C. J. (1983). Myoelectrical manifestations of localized muscular fatigue in humans. *Critical Reviews in Biomedical Engineering, 11*(4), 251-279.

De Luca, C. J. (1997). The use of surface electromyography in biomechanics. *Journal of Applied Biomechanics, 13*(2), 135-163.

De Luca, C. J., Gilmore, L. D., Kuznetsov, M., & Roy, S. H. (2010). Filtering the surface EMG signal: Movement artifact and baseline noise contamination. *Journal of biomechanics, 43*(8), 1573-1579.

DePoy, E., & Gitlin, L. N. (2011). *Introduction to research : understanding and applying multiple strategies* (4th ed.). Missouri: Elsevier/Mosby.

Digiovine, N. M., Jobe, F. W., Pink, M., & Perry, J. (1992). An electromyographic analysis of the upper extremity in pitching. *Journal of Shoulder and Elbow Surgery, 1*(1), 15-25.

Dolnicar, S. (2013). Asking good survey questions. *Journal of Travel Research, 52*(5), 551-574.

Dupont, G., Millet, G. P., Guinhouya, C., & Berthoin, S. (2005). Relationship between oxygen uptake kinetics and performance in repeated running sprints. *European Journal of Applied Physiology, 95*(1), 27-34.

Durall, C. J., Greene, P. F., & Kernozek, T. W. (2012). A Comparison of two isometric tests of trunk flexor endurance. *Journal of Strength and Conditioning Research, 26*(7), 1939-1944.

Ebenbichler, G. R., Oddsson, L. I. E., Kollmitzer, J., & Erim, Z. (2001). Sensory-motor control of the lower back: implications for rehabilitation. *Medicine and Science in Sports and Exercise, 33*(11), 1889-1898.

Ekstrom, R. A., Donatelli, R. A., & Carp, K. C. (2007). Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 37*(12), 754-762.

Ekstrom, R. A., Soderberg, G. L., & Donatelli, R. A. (2005). Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface EMG analysis. *Journal of Electromyography and Kinesiology, 15*(4), 418-428.

Escamilla, R. F., Babb, E., DeWitt, R., Jew, P., Kelleher, P., Burnham, T., et al. (2006). Electromyographic analysis of traditional and nontraditional abdominal exercises: Implications for rehabilitation and training. *Physical Therapy, 86*(5), 656-671.

Escamilla, R. F., Lewis, C., Bell, D., Bramblet, G., Daffron, J., Lambert, S., et al. (2010). Core muscle activation during Swiss ball and traditional abdominal exercises. *Journal of Orthopaedic & Sports Physical Therapy, 40*(8), 539-541.

Evans, K., Refshauge, K. M., & Adams, R. (2007). Trunk muscle endurance tests: Reliability, and gender differences in athletes. *Journal of Science and Medicine in Sport, 10*(6), 447-455.

Fernandes, C. M. B., Bouthillette, F., Raboud, J. M., Bullock, L., Moore, C. F., Christenson, J. M., et al. (1999). Violence in the emergency department: a survey of health care workers. *Canadian Medical Association Journal, 161*(10), 1245-1248.

Flegal, K. M., Shepherd, J. A., Looker, A. C., Graubard, B. I., Borrud, L. G., Ogden, C. L., et al. (2009). Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. *American Journal of Clinical Nutrition, 89*(2), 500-508.

Floyd, R. T. (2012). *Manual of structural kinesiology* (18th ed.). New York: McGraw-Hill.

Foa, E. B., Riggs, D. S., Dancu, C. V., & Rothbaum, B. O. (1993). Reliability and validity of a brief instrument for assessing posttraumatic-stress-disorder. *Journal of Traumatic Stress, 6*(4), 459-473.

Gaitanos, G. C., Williams, C., Boobis, L. H., & Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. *Journal of Applied Physiology, 75*(2), 712-719.

Garcia-Vaquero, M. P., Moreside, J. M., Brontons-Gil, E., Peco-Gonzalez, N., & Vera-Garcia, F. J. (2012). Trunk muscle activation during stabilization exercises with single and double leg support. *Journal of Electromyography and Kinesiology, 22*(3), 398-406.

Gastin, P. B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports Medicine, 31*(10), 725-741.

Giannesini, B., Cozzone, P. J., & Bendahan, D. (2003). Non-invasive investigations of muscular fatigue: metabolic and electromyographic components. *Biochimie, 85*(9), 873-883.

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-sprint ability - Part I factors contributing to fatigue. *Sports Medicine, 41*(8), 673-694.

Goodman, A. (1990). A model for police officer burnout. *Journal of Business and Psychology, 5*(1), 85-99.

Gordon, T., Thomas, C. K., Munson, J. B., & Stein, R. B. (2004). The resilience of the size principle in the organization of motor unit properties in normal and reinnervated adult skeletal muscles. *Canadian Journal of Physiology and Pharmacology, 82*(8-9), 645-661.

Grant, S., Corbett, K., Amjad, A. M., Wilson, J., & Aitchison, T. (1995). A comparison of methods of predicting maximum oxygen-uptake. *British Journal of Sports Medicine, 29*(3), 147-152.

Hatton, A. L., Dixon, J., Martin, D., & Rome, K. (2009). The effect of textured surfaces on postural stability and lower limb muscle activity. *Journal of Electromyography and Kinesiology, 19*(5), 957-964.

Heerwegh, D., & Loosveldt, G. (2008). Face-to-face versus web surveying in a high-internet-coverage population differences in response quality. *Public Opinion Quarterly, 72*(5), 836-846.

Henry, R. C., & Zivick, J. D. (1986). Principles of survey research. *Family Practice Research Journal, 5*(3), 145-157.

Heyward, V. H. (2010). *Advanced fitness assessment and exercise prescription* (6th ed.). Champaign, IL: Human Kinetics.

Hibbs, A. E., Thompson, K. G., French, D., Wrigley, A., & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine, 38*(12), 995-1008.

Hibbs, A. E., Thompson, K. G., French, D. N., Hodgson, D., & Spears, I. R. (2011). Peak and average rectified EMG measures: Which method of data reduction should be used for assessing core training exercises? *Journal of Electromyography and Kinesiology, 21*(1), 102-111.

Hislop, H. J., Avers, D., Brown, M., & Daniels, L. (2014). *Daniels and Worthingham's muscle testing: techniques of manual examination and performance testing* (9th ed.). Missouri.: Elsevier.

Hodgdon, J. A., & Jackson, A. S. (2000). Physical test validation for job selection. In S. Constable & B. Palmer (Eds.), *The process of physical standards development: SOAR* (pp. 139 - 177). Ohio: Human Systems Information Analysis Centre.

Hopmans, C. J., den Hoed, P. T., Wallenburg, I., van der Laan, L., van der Harst, E., van der Elst, M., et al. (2013). Surgeons' attitude toward a competency-based training and assessment program: Results of a multicenter survey. *Journal of Surgical Education, 70*(5), 647-654.

Johnson, D., Lynch, J., Nash, K., Cygan, J., & Mayhew, J. L. (2009). Relationship of lat-pull repetitions and pull-ups to maximal lat-pull and pull-up strength in men and women. *Journal of Strength and Conditioning Research, 23*(3), 1022-1028.

Jones, B. H., & Knapik, J. J. (1999). Physical training and exercise-related injuries: Surveillance, research and injury prevention in military populations. *Sports Medicine, 27*(2), 111-125.

Juker, D., McGill, S., Kropf, P., & Steffen, T. (1998). Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. *Medicine and Science in Sports and Exercise, 30*(2), 301-310.

Kaminsky, L. A., & ACSM. (2014). *ACSM's health-related physical fitness assessment manual* (4th ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Kelley, K., Clark, B., Brown, V., & Sitzia, J. (2003). Good practice in the conduct and reporting of survey research. *International Journal for Quality in Health Care, 15*(3), 261-266.

Kent-Braun, J. A. (1999). Central and peripheral contributions to muscle fatigue in humans during sustained maximal effort. *European Journal of Applied Physiology and Occupational Physiology, 80*(1), 57-63.

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy, 2*(3), 147.

Kinnear, T. C., & Taylor, J. R. (1996). *Marketing research: an applied approach* (5th ed.). New York: McGraw-Hill.

Kirchgassler, K. U. (1991). Validity: the quest for reality in quantitative and qualitative research. *Quality & Quantity, 25*(3), 285-295.

Kirshner, B., & Guyatt, G. (1985). A methodological framework for assessing health indexes. *Journal of Chronic Diseases, 38*(1), 27-36.

Knechtle, B., Baumann, B., Knechtle, P., & Rosemann, T. (2010). Speed during training and anthropometric measures in relation to race performance by male and female open-water ultra-endurance swimmers. *Perceptual and Motor Skills, 111*(2), 463-474.

Konrad, P. (2006). *The ABC of EMG: a practical introduction to kinesiological electromyography*. U.S.A: Noraxon.

Koukoubis, T. D., Cooper, L. W., Glisson, R. R., Seaber, A. V., & Feagin, J. A., Jr. (1995). An electromyographic study of arm muscles during climbing. *Knee Surgery, Sports Traumatology, Arthroscopy, 3*(2), 121-124.

Krosnick, J. A. (1999). Survey research. *Annual Review of Psychology, 50*, 537-567.

Kubo, K., Kanehisa, H., & Fukunaga, T. (2002). Effects of resistance and stretching training programmes on the viscoelastic properties of human tendon structures in vivo. *Journal of Physiology-London, 538*(1), 219-226.

Kubo, K., Kanehisa, H., Kawakami, Y., & Fukunaga, T. (2001). Influence of static stretching on viscoelastic properties of human tendon structures in vivo. *Journal of Applied Physiology, 90*(2), 520-527.

Kumar, D. K., Pah, N. D., & Bradley, A. (2003). Wavelet analysis of surface electromyography to determine muscle fatigue. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 11*(4), 400-406.

Labriola, J. E., Lee, T. Q., Debski, R. E., & McMahon, P. J. (2005). Stability and instability of the glenohumeral joint: The role of shoulder muscles. *Journal of Shoulder and Elbow Surgery, 14*(1), 32s-38s.

Larsson, L., Grimby, G., & Karlsson, J. (1979). Muscle strength and speed of movement in relation to age and muscle morphology. *Journal of Applied Physiology, 46*(3), 451-456.

Laurent, D., Portero, P., Goubel, F., & Rossi, A. (1993). Electromyogram spectrum changes during sustained contraction related to proton and diprotonated inorganic-phosphate accumulation: A P-31 nuclear-magnetic-resonance study on human calf muscles. *European Journal of Applied Physiology and Occupational Physiology, 66*(3), 263-268.

Lee, W. S., & Clark, L. (1997). *Task related physical fitness and performance standards: A Canadian Forces approach.* Canada: Department of National Defence.

Leger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences, 6*(2), 93-101.

Lehman, G. J. (2005). The influence of grip width and forearm pronation/supination on upper-body myoelectric activity during the flat bench press. *Journal of Strength and Conditioning Research, 19*(3), 587-591.

Lehman, G. J., Buchan, D. D., Lundy, A., Myers, N., & Nalborczyk, A. (2004). Variations in muscle activation levels during traditional latissimus dorsi weight training exercises: An experimental study. *Dynamic Medicine, 3*(1), 4.

Lehman, G. J., Hoda, W., & Oliver, S. (2005). Trunk muscle activity during bridging exercises on and off a Swiss ball. *Chiropractic and Osteopathy, 13*, 14.

Leslie, K. L. M., & Comfort, P. (2013). The effect of grip width and hand orientation on muscle activity during pull-ups and the lat pull-down. *Strength and Conditioning Journal, 35*(1), 75-78.

Levine, B. D. (2008). V-O2,V-max: what do we know, and what do we still need to know? *Journal of Physiology-London, 586*(1), 25-34.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 1-55.

Lindstedt, S. L., & Conley, K. E. (2001). Human aerobic performance: too much ado about limits to V-O2. *Journal of Experimental Biology, 204*(18), 3195-3199.

Lissitz, R. W., & Green, S. B. (1975). Effect of number of scale points on reliability: Monte-Carlo approach. *Journal of Applied Psychology, 60*(1), 10-13.

Lusk, S. J., Hale, B. D., & Russell, D. M. (2010). Grip width and forearm orientation effects on muscle activity during the lat pull-down. *Journal of Strength and Conditioning Research, 24*(7), 1895-1900.

Lynch, J. H., & Pallis, M. P. (2008). Clinical diagnoses in a Special Forces Group: The musculoskeletal burden. *Journal of Special Operations Medicine, 8*(2).

MacIsaac, D. T., Parker, P. A., Englehart, K. B., & Rogers, D. R. (2006). Fatigue estimation with a multivariable myoelectric mapping function. *Biomedical Engineering, 53*(4), 694-700.

Mackenzie, B. (2005). *101 performance evaluation tests*. London: Electric Word plc.

Marcora, S., & Miller, M. K. (2000). The effect of knee angle on the external validity of isometric measures of lower body neuromuscular function. *Journal of Sports Sciences, 18*(5), 313-319.

Marshall, P. W. M., Desai, I., & Robbins, D. W. (2011). Core stability exercises in individuals with and without chronic nonspecific low back pain. *Journal of Strength and Conditioning Research, 25*(12), 3404-3411.

Martinussen, M., Richardsen, A. M., & Burke, R. J. (2007). Job demands, job resources, and burnout among police officers. *Journal of Criminal Justice, 35*(3), 239-249.

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. *Annual Review of Psychology, 52*, 397-422.

Matthews, T. D., & Kostelis, K. T. (2011). *Designing and conducting research in health and human performance* (1st ed.). San Francisco: Jossey-Bass.

McCaw, S. T., & Melrose, D. R. (1999). Stance width and bar load effects on leg muscle activity during the parallel squat. *Medicine and Science in Sports and Exercise, 31*(3), 428-436.

Mccutcheon, M. C., Sticha, S. A., Giese, M. D., & Nagle, F. J. (1990). A further analysis of the 12-minute run prediction of maximal aerobic power. *Research Quarterly for Exercise and Sport, 61*(3), 280-283.

McGill, S., Andersen, J., & Cannon, J. (2014). Muscle activity and spine load during anterior chain whole body linkage exercises: the body saw, hanging leg raise and walkout from a push-up. *Journal of Sports Sciences*, 1-8.

McGill, S., Juker, D., & Kropf, P. (1996). Appropriately placed surface EMG electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine. *Journal of Biomechanics, 29*(11), 1503-1507.

McGill, S. M. (2001). Low back stability: from formal description to issues for performance and rehabilitation. *Exercise and Sport Sciences Reviews, 29*(1), 26-31.

McGill, S. M., Childs, A., & Liebenson, C. (1999). Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Archives of Physical Medicine and Rehabilitation, 80*(8), 941-944.

McGill, S. M., Grenier, S., Kavcic, N., & Cholewicki, J. (2003). Coordination of muscle activity to assure stability of the lumbar spine. *Journal of Electromyography and Kinesiology, 13*(4), 353-359.

McGill, S. M., & Karpowicz, A. (2009). Exercises for spine stabilization: motion/motor patterns, stability progressions, and clinical technique. *Archives of Physical Medicine and Rehabilitation, 90*(1), 118-126.

McKay, B. R., Paterson, D. H., & Kowalchuk, J. M. (2009). Effect of short-term high-intensity interval training vs. continuous training on O2 uptake kinetics, muscle deoxygenation, and exercise performance. *Journal of Applied Physiology, 107*(1), 128-138.

McNaughton, L., Hall, P., & Cooley, D. (1998). Validation of several methods of estimating maximal oxygen uptake in young men. *Perceptual and Motor Skills, 87*(2), 575-584.

Medved, V., & Cifrek, M. (2011). Kinesiological Electromyography. In V. Klika (Ed.), *Biomechanics in applications*. Croatia: InTech.

Merletti, R., & Hermens, H. (2000). Introduction to the special issue on the SENIAM European concerted action. *Journal of Electromyography and Kinesiology, 10*(5), 283-286.

Minick, K. I., Kiesel, K. B., Burton, L., Taylor, A., Plisky, P., & Butler, R. J. (2010). Interrater reliability of the functional movement screen. *The Journal of Strength & Conditioning Research, 24*(2), 479-486.

Moseley, G. L., Hodges, P. W., & Gandevia, S. C. (2002). Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements. *Spine (Phila Pa 1976), 27*(2), E29-36.

New Zealand Police. (2011). *STG required physical fitness policy*. Wellington: Human resources.

Nordander, C., Willner, J., Hansson, G. A., Larsson, B., Unge, J., Granquist, L., et al. (2003). Influence of the subcutaneous fat layer, as measured by ultrasound, skinfold calipers and BMI, on the EMG amplitude. *European Journal of Applied Physiology, 89*(6), 514-519.

Norton, K., & Olds, T. (Eds.). (2004). *Antropometrica: a textbook of body measurement for sports and health courses*. Sydney: UNSW Press.

Nuzzo, J. L., & Mayer, J. M. (2013). Body mass normalization for isometric tests of muscle endurance. *Journal of Strength and Conditioning Research, 27*(7), 2039-2045.

Panjabi, M. M. (1992). The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders, 5*(4), 383-389.

Parkes, J., Caravale, B., Marcelli, M., Franco, F., & Colver, A. (2011). Parenting stress and children with cerebral palsy: a European cross-sectional survey. *Developmental Medicine and Child Neurology, 53*(9), 815-821.

Payne, W., & Harvey, J. (2010). A framework for the design and development of physical employment tests and standards. *Ergonomics, 53*(7), 858-871.

Peterson, M. D., Rhea, M. R., & Alvar, B. A. (2005). Applications of the dose-response for muscular strength development: a review of meta-analytic efficacy and reliability for designing training prescription. *Journal of Strength and Conditioning Research, 19*(4), 950-958.

Phillips, K. A., Johnson, F. R., & Maddala, T. (2002). Measuring what people value: A comparison of "attitude" and "preference" surveys. *Health Services Research, 37*(6), 1659-1679.

Pink, M., Jobe, F. W., & Perry, J. (1990). Electromyographic analysis of the shoulder during the golf swing. *American Journal of Sports Medicine, 18*(2), 137-140.

Plowman, S. A., & Smith, D. L. (2014). *Exercise physiology for health, fitness, and performance* (4th ed.). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Portney, L. G., & Watkins, M. P. (2000). *Foundations of clinical research: applications to practice* (2nd ed.). New Jersey: Prentice Hall.

Powers, S. K., & Howley, E. T. (2009). *Exercise physiology: theory and application to fitness and performance* (7th ed.). New York: McGraw-Hill.

Powers, S. K., & Howley, E. T. (2012). *Exercise physiology : theory and application to fitness and performance* (8th ed.). New York: McGrawHill.

Pryor, R. R., Colburn, D., Crill, M. T., Hostler, D. P., & Suyama, J. (2012). Fitness characteristics of a suburban special weapons and tactics team. *Journal of Strength and Conditioning Research, 26*(3), 752-757.

Pyne, D. B., Trewin, C. B., & Hopkins, W. G. (2004). Progression and variability of competitive performance of Olympic swimmers. *Journal of Sports Sciences, 22*(7), 613-620.

Ramsbottom, R., Brewer, J., & Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine, 22*(4), 141-144.

Rayson, M. (2000). Fitness for work: the need for conducting a job analysis. *Occupational Medicine-Oxford, 50*(6), 434-436.

Rayson, M., Holliman, D., & Belyavin, A. (2000). Development of physical selection procedures for the British Army. Phase 2: Relationship between physical performance tests and criterion tasks. *Ergonomics, 43*(1), 73-105.

Reilly, T. (2010). Canada's physical fitness standard for the land force: A global comparison. *The Canadian Army, 13,* 59-69.

Ricci, B., Figura, F., Felici, F., & Marchetti, M. (1988). Comparison of male and female functional-capacity in pull-ups. *Journal of Sports Medicine and Physical Fitness, 28*(2), 168-175.

Roman-Liu, D., Tokarski, T., & Wojcik, K. (2004). Quantitative assessment of upper limb muscle fatigue depending on the conditions of repetitive task load. *Journal of Electromyography and Kinesiology, 14*(6), 671-682.

Ronai, P., & Scibek, E. (2014). The pull-up. *Strength and Conditioning Journal, 36*(3), 88-90.

Rubenfeld, G. D. (2004). Surveys: an introduction. *Respiratory Care, 49*(10), 1181-1185.

Samson, M. M., Meeuwsen, I. B. A. E., Crowe, A., Dessens, J. A. G., Duursma, S. A., & Verhaar, H. J. J. (2000). Relationships between physical performance measures, age, height and body weight in healthy adults. *Age and Ageing, 29*(3), 235-242.

Santana, J. C., Vera-Garcia, F. J., & McGill, S. M. (2007). A kinetic and electromyographic comparison of the standing cable press and bench press. *Journal of Strength and Conditioning Research, 21*(4), 1271-1277.

Scandura, T. A. (1992). Mentorship and career mobility: An empirical-investigation. *Journal of Organizational Behavior, 13*(2), 169-174.

Schellenberg, K. L., Lang, J. M., Chan, K. M., & Burnham, R. S. (2007). A clinical tool for office assessment of lumbar spine stabilization endurance: Prone and supine bridge maneuvers. *American Journal of Physical Medicine & Rehabilitation, 86*(5), 380-386.

Schmidt, W. C. (1997). World-Wide Web survey research: Benefits, potential problems, and solutions. *Behavior Research Methods Instruments & Computers, 29*(2), 274-279.

Sellentin, R., & Jones, R. (2012). The effect of core and lower limb exercises on trunk strength and lower limb stability on Australian soldiers. *Journal of Military and Veterans' Health, 20*(4), 15.

Signorile, J. F., Zink, A. J., & Szwed, S. P. (2002). A comparative electromyographical investigation of muscle utilization patterns using various hand positions during the lat pull-down. *Journal of Strength and Conditioning Research, 16*(4), 539-546.

Sinkowitz-Cochran, R. L. (2013). Survey design: To ask or not to ask? That is the question. *Clinical Infectious Diseases, 56*(8), 1159-1164.

Stewart, A. M., & Hopkins, W. G. (2000). Consistency of swimming performance within and between competitions. *Medicine and Science in Sports and Exercise, 32*(5), 997-1001.

Stokes, I. A., Henry, S. M., & Single, R. M. (2003). Surface EMG electrodes do not accurately record from lumbar multifidus muscles. *Clinical Biomechanics, 18*(1), 9-13.

Talebinejad, M., Chan, A. D. C., Miri, A., & Dansereau, R. M. (2009). Fractal analysis of surface electromyography signals: A novel power spectrum-based method. *Journal of Electromyography and Kinesiology, 19*(5), 840-850.

Tomlin, D. L., & Wenger, H. A. (2001). The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Medicine, 31*(1), 1-11.

Tong, T. K., Wu, S., & Nie, J. (2013). Sport-specific endurance plank test for evaluation of global core muscle function. *Physical Therapy in Sport*, 1-6.

Towler, M. C., Kaufman, S. J., & Brodsky, F. M. (2004). Membrane traffic in skeletal muscle. *Traffic, 5*(3), 129-139.

Turocy, P. S. (2002). Survey research in athletic training: The scientific method of development and implementation. *Journal of Athletic Training, 37*(4), s174-s179.

Vanderburgh, P. M., & Edmonds, T. (1997). The effect of experimental alterations in excess mass on pull-up performance in fit young men. *Journal of Strength and Conditioning Research, 11*(4), 230-233.

Vanderburgh, P. M., & Flanagan, S. (2000). The backpack run test: A model for a fair and occupationally relevant military fitness test. *Military Medicine, 165*(5), 418-421.

VanGeest, J. B., Johnson, T. P., & Welch, V. L. (2007). Methodologies for improving response rates in surveys of physicians: A systematic review. *Evaluation & the Health Professions, 30*(4), 303-321.

Vera-Garcia, F. J., Moreside, J. M., & McGill, S. M. (2010). MVC techniques to normalize trunk muscle EMG in healthy women. *Journal of Electromyography and Kinesiology, 20*(1), 10-16.

Vleeming, A., Poolgoudzwaard, A. L., Stoeckart, R., Vanwingerden, J. P., & Snijders, C. J. (1995). The posterior layer of the thoracolumbar fascia: Its function in load-transfer from spine to legs. *Spine, 20*(7), 753-758.

Voorn, V., Marang-van de Mheen, P., Wentink, M., So-Osman, C., Vlieland, T., Koopman-van Gemert, A., et al. (2013). Frequent use of blood-saving measures in elective orthopaedic surgery: a 2012 Dutch blood management survey. *BMC Musculoskeletal Disorders, 14*(8), 230.

Weigall, F. (2006). *Marine pilot transfers: A preliminary investigation of options*. Australia: Australian Transport Safety Bureau.

Willardson, J. M. (2007). Core stability training: Applications to sports conditioning programs. *Journal of Strength and Conditioning Research, 21*(3), 979-985.

Williams, A. G., Rayson, M. P., & Jones, D. A. (1999). Effects of basic training on material handling ability and physical fitness of British Army recruits. *Ergonomics, 42*(8), 1114-1124.

Witvrouw, E., Mahieu, N., Danneels, L., & McNair, P. (2004). Stretching and injury prevention: An obscure relationship. *Sports Medicine, 34*(7), 443-449.

Wood, M., Cronin, J., & Hopkins, W. (2004). *Special Tactical Group physical assessment battery: Test protocol, standards and recommendations*. New Zealand: Auckland University of Technology.

Yoshitake, Y., Ue, H., Miyazaki, M., & Moritani, T. (2001). Assessment of lower-back muscle fatigue using electromyography, mechanomyography, and near-infrared spectroscopy. *European Journal of Applied Physiology, 84*(3), 174-179.

Youdas, J. W., Amundson, C. L., Cicero, K. S., Hahn, J. J., Harezlak, D. T., & Hollman, J. H. (2010). Surface electromyographic activation patterns and elbow joint motion during a pull-up, chin-up, or perfect-pullup (Tm) Rotational Exercise. *Journal of Strength and Conditioning Research, 24*(12), 3404-3414.

Youdas, J. W., Guck, B. R., Hebrink, R. C., Rugotzke, J. D., Madson, T. J., & Hollman, J. H. (2008). An electromyographic analysis of the Ab-Slide exercise, abdominal crunch, supine double leg thrust, and side bridge in healthy young adults: implications for rehabilitation professionals. *Journal of Strength and Conditioning Research, 22*(6), 1939-1946.

Zwarts, M. J., Bleijenberg, G., & van Engelen, B. G. M. (2008). Clinical neurophysiology of fatigue. *Clinical Neurophysiology, 119*(1), 2-10.

16. APPENDICES

Appendix A. Letter of low risk ethical approval - Phase One

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

4 April 2013

James Dickie
97 St Andrews Road
Plimmerton
PORIRUA 5026

Dear James

Re: Review of Armed Offenders Squad and Special Tactics Group Fitness Policy for the New Zealand Police

Thank you for your Low Risk Notification which was received on 7 March 2013.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

J. O'Neill

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Dr Sally Lark
School of Sport and Exercise
Wellington

Mr Matthew Barnes
School of Sport and Exercise
PN621

Mr James Faulkner
School of Sport and Exercise
Wellington

Prof Steve Stannard, HoS
School of Sport and Exercise
PN621

Massey University Human Ethics Committee
Accredited by the Health Research Council

Research Ethics Office
Massey University, Private Bag 11222, Palmerston North 4442, New Zealand T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz www.massey.ac.nz

Appendix B. Information sheet - Phase One

College of Health
School of Sport and Exercise
Massey University
Private Bag 756
Wellington 6140

Review of Armed Offenders Squad (AOS) and Special Tactics Group (STG) fitness policies for the New Zealand Police.

INFORMATION SHEET

This research is to be conducted through Massey University on behalf of the New Zealand Police by James Dickie (Master of Health Science endorsing Sport and Exercise); with a supervisory team of Dr. Sally Lark, Dr. James Faulkner and Dr. Matt Barnes. The purpose of this survey is to gather data in relation to demographics, training practices and job demands of the AOS and STG.

This survey is part one of a larger project which will endeavour to provide a detailed review of the physical fitness policies of the New Zealand Police AOS and STG. As current or previous members of the AOS or STG we would like to invite you to participate in this research.

Email addresses for each member of the AOS and STG were provided by Superintendent Bruce Dunstan. Each member of the research team has signed a deed of confidentiality, and undergone background checks at the request of the New Zealand Police. As this research is specific to the AOS and STG we seek to recruit participants that are current or previous members of the AOS or STG over the past five years.

This research will require participants to complete the attached web-based survey questionnaire. The survey will take approximately 25 minutes to complete.

Data from this survey will undergo statistical analysis by the research team to determine the perceived relevance of the current fitness standards/tests to job demands. Furthermore, the research will seek to identify some of the drivers for choosing to undergo the selection tests or not, whether candidates thought themselves sufficiently prepared for the selection tests and to highlight areas in testing that candidates are failing/struggling with. Any statistical data presented to the New Zealand Police will be on a group basis only. **All information gathered throughout this research project will remain anonymous and strictly confidential**. Online data will be stored in a password protected account, while sets of physical data will be stored at Massey University in a secure location. In order for the data to be of value I ask that all questions be answered as truthfully as possible.

You are under no obligation to accept this invitation. Completion and return of the questionnaire implies consent. You have the right to decline to answer any particular question.

Project Contacts

James Dickie	Email: j.dickie@massey.ac.nz	ph: 0274170806
Dr. Sally Lark	Email: s.lark@massey.ac.nz	
Dr. James Faulkner	Email: j.faulkner@massey.ac.nz	
Dr. Matt Barnes	Email: m.barnes@massey.ac.nz	

If you have any queries relating to this research project then feel free to contact the researcher and/or supervisors. Alternately, if there are any concerns raised then contact may be made with Superintendent Bruce Dunstan at Bruce.Dunstan@police.govt.nz

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email humanethics@massey.ac.nz".

Appendix C. Web-based survey questionnaire for AOS and STG members

Review of Armed Offenders Squad (AOS) and Special Tactics Group (STG) fitness policies for the New Zealand Police

The purpose of this survey is to gather data in relation to demographics, training practices and job demands of the AOS and STG. The research is being conducted through Massey University on behalf of the New Zealand Police. This survey is part one of a larger project which will endeavour to provide a detailed review of the physical fitness policies of the New Zealand Police AOS and STG.

Participation in this survey is voluntary and any information gathered will be anonymous, any statistical data presented to the New Zealand Police will be on a group basis only. All information gathered throughout this research project will remain strictly confidential. In order for the data to be of value I ask that all questions be answered as truthfully as possible.

By choosing to submit this survey you hereby give consent for the information to be used in our data analysis.

The survey will take approximately 25 minutes to complete. We would like to thank you for your participation.

*Required

1. **Please specify your gender**
   Mark only one oval.
   - ( ) Male
   - ( ) Female

2. **What is your age?**
   Mark only one oval.
   - ( ) 18-22
   - ( ) 23-27
   - ( ) 28-32
   - ( ) 33-37
   - ( ) 38-42
   - ( ) 43+

3. **Please specify your ethnicity**
   Tick all that apply.
   - [ ] European
   - [ ] Maori
   - [ ] Pacific Islander
   - [ ] Asian
   - [ ] Indian
   - [ ] Other: ____________

4. **What is your current marital status**
   Mark only one oval.
   - ( ) Married
   - ( ) In a relationship
   - ( ) Not in a relationship

5. **Do you have any children?**
   Mark only one oval.
   - ( ) Yes
   - ( ) No

6. **If Yes, How Many?**

   ____

7. **Do you own your own home?**
   Mark only one oval.
   - ( ) Yes
   - ( ) No

8. **What is your highest level of secondary school education?**
Mark only one oval.
- ◯ NCEA Level 1 / 5th Form
- ◯ NCEA Level 2 / 6th Form
- ◯ NCEA Level 3 / 7th Form

9. **Do you have any tertiary education?**
Mark only one oval.
- ◯ Yes
- ◯ No

10. **If Yes, what is your highest level?**
Mark only one oval.
- ◯ Diploma
- ◯ Bachelors Degree
- ◯ Masters Degree
- ◯ Doctoral Degree

11. **Please indicate your spoken languages**
Tick all that apply.
- ☐ English
- ☐ Maori
- ☐ Samoan
- ☐ Mandarin/Cantonese
- ☐ Other: ____________

12. **In which city/town do you reside?**

____

13. **Is this the same city/town in which you are primarily stationed?**
Mark only one oval.
- ◯ Yes
- ◯ No

14. **If No, which city/town are you stationed?**

____

15. **All current members please indicate what Police group you belong to (old-members select highest level) ***
Mark only one oval.
- ◯ AOS *Skip to question 16.*
- ◯ STG *Skip to question 20.*

16. **In order to be a part of the STG would you move to one of the 3 cities where the STG are based?**
Mark only one oval.
- ◯ Yes
- ◯ No

17. **If yes, please rank regions in order of preference**
Mark only one oval per row.

	1st Choice	2nd Choice	3rd Choice
Auckland	◯	◯	◯
Wellington	◯	◯	◯
Christchurch	◯	◯	◯

18. What would be your MAJOR CONSIDERATIONS about moving from your current residence to one of the three STG locations (tick as many as appropriate):
Tick all that apply.

- [ ] Family
- [ ] Housing
- [ ] Living costs
- [ ] Friends
- [ ] Lifestyle
- [ ] Hobbies
- [ ] Location
- [ ] Pets
- [ ] Transportation
- [ ] Businesses
- [ ] Ethnicity/culture
- [ ] Other: ____________

19. Do you think a role as an STG operator would inhibit your progress within the police ranks?
Mark only one oval.

- ( ) Yes
- ( ) No

20. Do you perceive the STG to be an appealing role within the police force?
Mark only one oval.

- ( ) Yes
- ( ) No

21. Please state why

____

22. End of part 1 generic questions. Please feel free to provide any further comments below.

____

23. Did you take any leave to train for the AOS selection course?
Mark only one oval.

- ( ) Yes
- ( ) No *Skip to question 26.*

24. How much leave did you take (in weeks)?

____

25. Was this leave paid or unpaid?
Mark only one oval.

- ( ) Paid
- ( ) Unpaid

26. **For how many weeks did you train SPECIFICALLY for the AOS selection course**
Mark only one oval.

- 1-4 weeks
- 5-8 weeks
- 9-12 weeks
- 13-16 weeks
- 17-20 weeks
- 21-24 weeks
- 25-28 weeks
- 28+ weeks

27. **PRIOR to being nominated for the AOS selection course, on average how many hours of physical training did you complete each week:**
Mark only one oval.

- 1-4
- 4-8
- 8-12
- 12-16
- 16-20
- 20-24
- 24-28
- 28+

28. **On average, how many hours of training did you complete each week WHILST TRAINING specifically for the AOS selection course:**
Mark only one oval.

- 1-4
- 4-8
- 8-12
- 12-16
- 16-20
- 20-24
- 24-28
- 28+

29. **Have you sustained any ongoing injury as a result of training for AOS selection?**
Mark only one oval.

- Yes
- No

30. **If yes, please give details**
(what kind of injury was sustained, severity, ability to train/work, duration of pain etc.)

31. **ONCE A MEMBER of the AOS how many hours of physical training did/do you complete each week on average:**
Mark only one oval.

- 1-4
- 4-8
- 8-12
- 12-16
- 16-20
- 20-24
- 24-28
- 28+

32. Have you sustained any ongoing injury as a result of AOS maintenance training?
Mark only one oval.

- Yes
- No

33. If yes, please give details
(what kind of injury was sustained, severity, ability to train/work, duration of pain etc.)

34. Prior to selection into AOS did you have any aspiration to move onto STG?
Mark only one oval.

- Yes
- No

35. Did this aspiration change once in the AOS?
Mark only one oval.

- Yes
- No

36. Please specify reasons why
eg. time, danger, motivation

AOS Selection Tests

Please rate each of the following AOS selection tests in terms of relevance to job demands:

37. 50m Swim
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

38. 25m Tow Unassisted
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

39. 400m Continuous Swim
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

40. 4hr Jerry-Can Walk
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

41. 12km Pack March/Run
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

42. 100m Firemans Carry
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

43. 1.8m PCT Wall
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

44. 1.8m PCT Long Jump
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

45. 6m PCT Rope Climb
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

46. Glock & M4 Shoot
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

47. Coopers 12min Run
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

Out of the following tests

(50m Swim, 25m Tow Unassisted, 400m Continuous Swim, 4hr Jerry-Can Walk, 12km Pack March/Run, 100m Firemans Carry, PCT rope, PCT wall/jump, Coopers 12min run, Glock & M4 Shoot)

48. Whist training for the AOS selection course which test did you train the LEAST for?
Mark only one oval.

- ◯ 50m Swim
- ◯ 25m Tow Unassisted
- ◯ 400m Continuous Swim
- ◯ 4hr Jerry-Can Walk
- ◯ 12km Pack March/Run
- ◯ 100m Firemans Carry
- ◯ PCT rope
- ◯ PCT wall/jump
- ◯ Coopers 12min run
- ◯ Glock and M4 shoot

49. Whilst training for the AOS selection course which did you train the MOST for?
Mark only one oval.

- 50m Swim
- 25m Tow Unassisted
- 400m Continuous Swim
- 4hr Jerry-Can Walk
- 12km Pack March/Run
- 100m Firemans Carry
- PCT rope
- PCT wall/jump
- Coopers 12min run
- Glock & M4 Shoot

50. Which did you find the easiest
Mark only one oval per row.

	50m swim	25m tow	400m continuous swim	4hr Jerry-can walk	12km pack march/run	100m firemans carry	PCT rope	PCT wall/jump	Coopers 12min run	Glock and M4 shoot
Easiest										
Second easiest										
Third easiest										

51. Which did you find the hardest
Mark only one oval per row.

	50m swim	25m tow	400m continuous swim	4hr Jerry-can walk	12km pack march/run	100m firemans carry	PCT rope	PCT wall/jump	Coopers 12min run	Glock and M4 shoot
Hardest										
Second hardest										
Third hardest										

ACSM Fundamental Components

The following 5 questions each have a definition relating to the ACSM fundemental components of physical fitness. Please answer the questions in relation to the AOS job demands.

52. How relevant do you perceive muscular strength is to job demands?
Muscular strength is the maximal force produced by a muscle or muscle group in order to overcome resistance.
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

53. How relevant do you perceive cardiovascular fitness is to job demands?
Cardiovascular fitness is the ability to deliver oxygen to working muscles in order to sustain physical activity.
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

54. How relevant do you perceive muscular endurance is to job demands?
Muscular endurance is the ability of a muscle or muscle group to sustain repeated contractions, or maintain a position for a period of time.
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

55. How relevant do you perceive flexibility is to job demands?
Flexibility is the maximal length a muscle will stretch.
Mark only one oval.

	1	2	3	4	5	
Little Relevance						High Relevance

56. **How relevant do you perceive a good body composition is to job demands?**
Body composition is the proportion of fat mass to lean muscle mass.
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

57. **How would you rate your current level of physical fitness in comparison to when you initially passed the AOS selection course:**
Mark only one oval.

	1	2	3	4	5	
Less Fit	◯	◯	◯	◯	◯	More Fit

58. **Are there any changes you would suggest to be made to the AOS selection course?**

59. **Do you think it would be beneficial for the AOS to have a more specific annual fitness assessment?**
Mark only one oval.

◯ Yes
◯ No

60. **If the STG component was included at the end of the AOS selection course would you consider completing the additional day to enable a possible career in the STG?**
Mark only one oval.

◯ Yes
◯ No

61. **Have you attended AND failed a STG selection course? ***
Mark only one oval.

◯ Yes *Skip to question 62.*
◯ No *Skip to question 69.*

62. **In what area of testing did you fail?**
Mark only one oval.

◯ Rope pull-ups
◯ Stair climb
◯ Three-point bridge
◯ Beep test
◯ 400m swim
◯ Jerry-can walk
◯ Kaukau pack walk
◯ M4 shoot
◯ Ship ladder climb
◯ 12km march/run
◯ Firemans carry
◯ 6m PCT rope
◯ PCT wall/jump
◯ Sandbag

63. **Other**

64. **If applying for the selection course again, what would you do differently?**

65. **Would you reapply for the STG selection course?**
Mark only one oval.

- ◯ Yes
- ◯ No

66. **If No, Please explain why**

67. **Do you feel that the selection course was fair?**
Mark only one oval.

- ◯ Yes
- ◯ No

68. **If No, Please explain why**

69. **Do you feel that your training regime leading up to the AOS selection course was correct?**
Mark only one oval.

- ◯ Yes
- ◯ No

70. **Were you provided with advice or a training programme for your preparation?**
Mark only one oval.

- ◯ Yes
- ◯ No

71. **If Yes, who/where did you get this information from?**

72. **What is/was your length of AOS service in years?**

73. **Are you a current or previous STG member? ***
Mark only one oval.

- ◯ Yes
- ◯ No *Stop filling out this form.*

All STG members please continue answering until end of survey

if you are not a current or previous STG member please go back to previous page and click no

74. Did you take any leave to train for the STG selection course?
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 77.*

75. If Yes, How many weeks?

____

76. Was this leave paid or unpaid?
Mark only one oval.

- ◯ Paid
- ◯ Unpaid

77. For how many weeks did you train SPECIFICALLY for the STG selection course?
Mark only one oval.

- ◯ 1-4 weeks
- ◯ 5-8 weeks
- ◯ 9-12 weeks
- ◯ 13-16 weeks
- ◯ 17-20 weeks
- ◯ 21-24 weeks
- ◯ 25-28 weeks
- ◯ 28+ weeks

78. PRIOR to being nominated for the STG selection course on average how many hours of physical training did you do each week?
Mark only one oval.

- ◯ 1-4
- ◯ 4-8
- ◯ 8-12
- ◯ 12-16
- ◯ 16-20
- ◯ 20-24
- ◯ 24-28
- ◯ 28+

79. On average, how many hours of physical training did you complete each week WHILST TRAINING for the STG selection course?
Mark only one oval.

- ◯ 1-4
- ◯ 4-8
- ◯ 8-12
- ◯ 12-16
- ◯ 16-20
- ◯ 20-24
- ◯ 24-28
- ◯ 28+

80. Have you sustained any ongoing injury as a result of training for STG selection?
Mark only one oval.

- ◯ Yes
- ◯ No

81. If yes, plase provide details
(what kind of injury was sustained, severity, ability to train/work, duration of pain etc.)

____
____
____
____

82. **ONCE SELECTED into the STG, on average how many hours of physical training did/do you complete each week?**
Mark only one oval.

- 1-4
- 4-8
- 8-12
- 12-16
- 16-20
- 20-24
- 24-28
- 28+

83. **Have you sustained any ongoing injury as a result of STG MAINTENANCE training?**
Mark only one oval.

- Yes
- No

84. **If yes, please provide details**
(what kind of injury was sustained, severity, ability to train/work, duration of pain etc.)

85. **On a day to day basis how physically demanding do you find the role of an STG operator**
Mark only one oval.

	1	2	3	4	5	
Not Demanding	◯	◯	◯	◯	◯	Very Demanding

86. **When ON DEPLOYMENT how physically demanding is the role of STG operator**
Mark only one oval.

	1	2	3	4	5	
Not Demanding	◯	◯	◯	◯	◯	Very Demanding

87. **On a day to day basis how mentally demanding do you find the role of an STG operator**
Mark only one oval.

	1	2	3	4	5	
Not Demanding	◯	◯	◯	◯	◯	Very Demanding

88. **When ON DEPLOYMENT how mentally demanding do you find the role of an STG operator**
Mark only one oval.

	1	2	3	4	5	
Not Demanding	◯	◯	◯	◯	◯	Very Demanding

In your time as an STG operator how often ON DEPLOYMENT have you completed the following:

89. **5km run**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

90. **12km march/run**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

91. **20+ km march/run**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

92. **Blue Role**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

93. **Ship ladder climb**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

94. **Rapelling**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

95. **Bush Surveillance**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

96. **Infiltration**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

97. **Use of physical force**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

98. **Use of firearms**
Mark only one oval.

	1	2	3	4	5	
Not Often	◯	◯	◯	◯	◯	Very Often

Please rate each of the following STG selection tests in terms of RELEVANCE to JOB DEMANDS

99. **Rope Pull-Ups**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

100. **Stair Climb**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

101. **Three-Point Bridge**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

102. **Beep Test**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

103. **400m Swim**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

104. **Jerry-Can Walk**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

105. **Kaukau Pack Walk**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

106. **M4 Shoot**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

107. **Ship Ladder Climb**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

108. **12km Pack March/Run**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

109. **Firemans Carry**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

110. **6m PCT Rope**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

111. **PCT wall/long jump**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

112. **Sandbag exercise**
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

Out of the following tests:

Rope pull-ups, Stair climb, Three-point bridge, Beep test, 400m swim, Jerry-can walk, Kaukau pack walk, M4 shoot, Ship ladder climb, 12km march/run, Firemans carry, 6m PCT rope, PCT wall/jump, sandbag exercise

113. **Which did you find the most DIFFICULT during selection**
Mark only one oval per row.

	Rope pull ups	Stair climb	Three-point bridge test	Beep test	400m swim	Jerry-can walk	Kaukau pack walk	M4 shoot	Ship ladder climb	12km pack march/run	Firemans carry	PCT rope	PCT wall/jump	Sandbag exercise
Hardest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Second hardest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Third hardest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

114. **Which did you find the EASIEST during selection**
Mark only one oval per row.

	Rope pull ups	Stair climb	Three-point bridge test	Beep test	400m swim	4hr Jerry-can walk	Kaukau pack walk	M4 shoot	Ship ladder climb	12km pack march/run	Firemans carry	PCT rope	PCT wall/jump	Sandbag exercise
Easiest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Second easiest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Third easiest	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

115. **Which tests did you train the MOST for?**
Mark only one oval per row.

	Rope pull ups	Stair climb	Three-point bridge test	Beep test	400m swim	Jerry-can walk	Kaukau pack walk	M4 shoot	Ship ladder climb	12km pack march/run	Firemans carry	PCT rope	PCT wall/jump	Sandbag exercise
Most	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Second most	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Third most	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

116. **Which tests did you train the LEAST for**
Mark only one oval per row.

	Rope pull ups	Stair climb	Three-point bridge test	Beep test	400m swim	Jerry-can walk	Kaukau pack walk	M4 shoot	Ship ladder climb	12km pack march/run	Firemans carry	PCT rope	PCT wall/jump	Sandbag exercise
Least	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Second least	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Third least	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

ACSM Fundamental Components

The following five questions each have a definition relating to the ACSM fundamental components of physical fitness. Please answer the questions in relation to the STG job demands.

117. **How relevant do you perceive muscular strength is to job demands?**
Muscular strength is the maximal force produced by a muscle or muscle group in order to overcome a resistance.
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

118. How relevant do you perceive cardiovascular fitness is to job demands?
Cardiovascular fitness is the ability to deliver oxygen to working muscles in order to sustain physical activity.
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

119. How relevant do you perceive muscular endurance is to job demands?
Muscular endurance is the ability of a muscle or muscle group to sustain repeated contractions, or maintain a position for a period of time.
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

120. How relevant do you perceive flexibility is to job demands?
Flexibility is the maximal length a muscle will stretch.
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

121. How relevant do you perceive a good body composition is to job demands?
Body composition is the proportion of fat mass to lean muscle mass.
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

122. How relevant did you find the STG selection course to your role as an STG operator?
Mark only one oval.

	1	2	3	4	5	
Little Relevance	◯	◯	◯	◯	◯	High Relevance

123. Are there any changes you would make to the STG selection course?

124. How relevant do you find the annual fitness assessment to job demands?
Mark only one oval.

	1	2	3	4	5	
Little Relevence	◯	◯	◯	◯	◯	High Relevence

125. Do you think it is beneficial to have an annual fitness assessment?
Mark only one oval.

◯ Yes
◯ No

126. Do you feel that the annual fitness assessment is an adequate level of strength and fitness for deployment?
Mark only one oval.

◯ Yes
◯ No

127. At this current point of time do you feel that you could pass the annual fitness assessment?
Mark only one oval.

◯ Yes
◯ No

STG Service Length

128. **What is/was your length of STG service in years?**

129. **Do you have any comments/suggestions about the STG annual fitness assessment?**

Powered by
Google Forms

Appendix D. Web-based survey questionnaire for unsuccessful AOS selection

Review of Armed Offenders Squad (AOS) and Special Tactics Group (STG) fitness policies for the New Zealand Police

The purpose of this survey is to gather data in relation to demographics, training practices and job demands of the AOS and STG. The research is being conducted through Massey University on behalf of the New Zealand Police. This survey is part one of a larger project which will endeavour to provide a detailed review of the physical fitness policies of the New Zealand Police AOS and STG.

Participation in this survey is voluntary and any information gathered will be anonymous, any statistical data presented to the New Zealand Police will be on a group basis only. All information gathered throughout this research project will remain strictly confidential. In order for the data to be of value I ask that all questions be answered as truthfully as possible.

By choosing to submit this survey you hereby give consent for the information to be used in our data analysis.

The survey will take approximately five minutes to complete. We would like to thank you for your participation.

*Required

1. **Have you attended and failed an AOS selection course? ***
   Mark only one oval.
   - ◯ Yes
   - ◯ No *Stop filling out this form.*

2. **In what area of testing did you fail?**
   Mark only one oval.
   - ◯ 50m swim
   - ◯ 25m tow unassisted
   - ◯ 400m continuous swim
   - ◯ 4hr Jerry-can walk
   - ◯ 12km pack march/run
   - ◯ PCT wall/jump
   - ◯ PCT rope
   - ◯ Coopers 12min run
   - ◯ Glock and M4 shoot
   - ◯ 100m firemans carry

3. **Please state if failed in a different area**

4. **For how many weeks did you train SPECIFICALLY for the AOS selection course**
Mark only one oval.

- 1-4
- 5-8
- 9-12
- 13-16
- 17-20
- 21-24
- 25-28
- 28+

5. **PRIOR to deciding to attend the AOS selection course, on average how many hours of physical training did you complete each week:**
Mark only one oval.

- 1-4
- 5-8
- 9-12
- 13-16
- 17-20
- 21-24
- 25-28
- 28+

6. **Were you provided with advice or a training programme for your preparation?**
Mark only one oval.

- No
- Yes

7. **If yes, who/where did you get this advice from?**

8. **Do you feel that your training regime leading up to the selection course was correct?**
Mark only one oval.

- ◯ Yes
- ◯ No

9. **If applying for the selection course again, what would you do differently?**

____
____
____
____
____

10. **Do you feel that the selection course was fair?**
Mark only one oval.

- ◯ Yes
- ◯ No

11. **If no, for what reasons?**

____
____
____
____
____

12. **Would you reapply for the AOS selection course?** *
Mark only one oval.

- ◯ Yes *Stop filling out this form.*
- ◯ No

13. **If no, why?**

____
____
____
____
____

Powered by
Google Forms

Appendix E. Letter of invitation - Phase Two

MASSEY UNIVERSITY

College of Health
School of Sport and Exercise
Massey University
Private Bag 756
Wellington 6140

Date

Dear

As a current STG operator we would like to invite you to take part in a research study analysing the muscle activity associated with four of the STG selection tasks including:

- Rope pull-ups
- PCT rope climb
- Ships ladder climb
- 12-minute bridge

An information sheet is attached outlining the study. Participation is completely voluntary and all information gathered is confidential. The study will take place at Police training facilities located in Auckland, Wellington and Christchurch. You will be required for testing on three separate occasions. Each testing session will last no longer than 1.5 hours. The dates are yet to be confirmed, but will be in consultation with team leaders and Superintendent Bruce Dunstan.

Please read the attached information sheet and contact me if you would like to participate. If you wish to participate an informed consent form will provided on the first day of testing.

If you have any questions about the study or require further information please do not hesitate to contact me by email j.dickie@massey.ac.nz or by phone 0274170806.

Yours sincerely

James Dickie

Postgraduate student
Massey University

Appendix F. Information sheet - Phase Two

College of Health
School of Sport and Exercise
Massey University
Private Bag 756
Wellington 6140

Review of Armed Offenders Squad (AOS) and Special Tactics Group (STG) fitness policies for the New Zealand Police.

INFORMATION SHEET

Thank you for showing an interest in this study. Please read everything below before deciding if you wish to participate. This information sheet will tell you a little more about the study and what we would like you to do.

What is the purpose of this research?

This research is to be conducted through Massey University on behalf of the New Zealand Police by James Dickie (Master of Health Science endorsing Sport and Exercise) supervised by Dr. Sally Lark, Dr. James Faulkner and Dr. Matt Barnes. The purpose of this research is to determine the relevance of the rope pull ups and 12-minute bridge test to the role of an STG operator. This research is part two of a project which will endeavour to provide a detailed review of the physical assessment policies of the New Zealand Police AOS and STG. Each member of the research team has signed a deed of confidentiality, and undergone background checks at the request of the New Zealand Police.

As current members of the STG we would like to invite you to participate in this research.

Who can take part in this study?

You are eligible to participate if you are a current STG operator. Unfortunately you will not be eligible if you have any injuries which may prevent involvement in physical activity, any cardiovascular health risks or allergy to electrode adhesive. You will be asked to complete a Health History Questionnaire and physical activity readiness questionnaire prior to participation in the study to help identify any conditions you may have for inclusion / exclusion from the study. Although familiar with the tasks to be performed, it must be noted that testing could result in muscle pain or discomfort.

How long and where will this study take place?

You will be tested on three consecutive occasions at Police training facilities located in Auckland, Wellington or Christchurch. Each testing session will last no longer than 1.5 hours on day one, and 1 hour on days two and three. You will be asked to not partake in heavy exercise 48 hours prior to testing.

What will happen?

This study will use recording electrodes placed on the skin's surface to measure muscle activity during certain tasks, a video camera will also be used to record the specific tasks being performed. On day one of testing we will ask you to sign informed consent before any testing takes place. You will then be asked to fill out the health questionnaires. Your height, weight, and arm length will be taken. Electrodes will be stuck to the skin above muscles on the forearm, bicep, shoulder, chest and upper back; this will require us to shave any hair on the site of electrode placement approximately the size of two 50c coins. You will then be asked to perform one of the following tasks:

- Rope pull-ups to failure
- 6m PCT rope climb x 3
- 6m caving (ships) ladder climb x 3

Day two involves completion of the remaining two tasks.

The final day will involve recording electrodes being placed above various muscles of the abdomen and back, and completion of the 12-minute rotational bridge. You will be asked to warm up for five minutes before the exercise tasks.

What will happen to this information?

All collected information will be kept by the researchers. Any data presented will be on a group basis only. **All information gathered throughout this research project will remain anonymous and strictly confidential**. We may ask you at a later date via email to provide written consent to use still images obtained from the video recordings in the final report. These images will show a visual representation of the tasks being performed and any identifiable features will be blacked out. We may use the data that we collect in publications or during presentations, but no one will be able to tell which data is yours. At the end of the project, a summary of findings will be sent to you via email within six months from the completion of data collection.

You are under no obligation to accept this invitation. You have the right to:

- decline to answer any particular question;
- withdraw from the study at any point of time until completion of final day of testing;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

Project Contacts

James Dickie	Email: j.dickie@massey.ac.nz	ph: 0274170806
Dr. Sally Lark	Email: s.lark@massey.ac.nz	
Dr. James Faulkner	Email: j.faulkner@massey.ac.nz	
Dr. Matt Barnes	Email: m.barnes@massey.ac.nz	

If you have any queries relating to this research project then feel free to contact the researcher and/or supervisors. Alternately, if there are any concerns raised then contact may be made with Superintendent Bruce Dunstan at Bruce.Dunstan@police.govt.nz

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/71. If you have any concerns about the conduct of this research, please contact Dr Brian Finch, Chair, Massey University Human Ethics Committee: Southern A, telephone 06 350 5799 x 84459, email humanethicsoutha@massey.ac.nz.

Compensation for Injury

If physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Accident Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access those entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings, and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury.

If your ACC claim is not accepted you should immediately contact the researcher. The researcher will initiate processes to ensure you receive compensation equivalent to that to which you would have been entitled had ACC accepted your claim.

Appendix G. Health history questionnaire

Health History Questionnaire

NAME________________________________ AGE _____
First M.I Last

FAMILY HISTORY (Have any immediate family or grandparents had?)	**YES**	**NO**
Heart attack	☐	☐
Stroke	☐	☐
Heart operations	☐	☐
Died suddenly before age 55 (male) or age 65 (female)	☐	☐

PAST HISTORY (Have you ever had?)	**YES**	**NO**
High blood pressure	☐	☐
Lung disease	☐	☐
High cholesterol	☐	☐
Kidney disease	☐	☐
Hepatitis	☐	☐
Diabetes	☐	☐
Heart attack	☐	☐

PRESENT SYMPTOMS (Have you recently had?)	**YES**	**NO**
Heart palpitations	☐	☐
Skipped heart beats	☐	☐
Cough on exertion	☐	☐
Coughing of blood	☐	☐
Frequent headaches	☐	☐
Cold or flu	☐	☐
Back Pain	☐	☐

Do you have any current injury? YES NO

Please detail injury (include location of injury & any activities that may aggravate injury)

____

____

____

Have you engaged in a regular (3x per week) **strength training programme for the past six months:**

YES NO

Do you currently smoke? YES NO

Have you ever quit smoking? YES NO

Have you ever had:

YES	**NO**	
☐	☐	Previous shoulder subluxation, dislocation or fracture?
☐	☐	History of joint instability, tendinitis, bursitis, impingement or neuromuscular complications?
☐	☐	Numbness or tingling in upper extremity, neck or back during pull-ups?

Signed ________________________________Date ______________________________

Appendix H. Physical activity readiness questionnaire

PAR-Q & YOU

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with your doctor before you start.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check **YES** or **NO**

YES ☐	NO☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommende by a doctor?**
YES ☐	NO☐	**2. Do you feel pain in your chest when you do physical activity?**
YES ☐	NO☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
YES ☐	NO☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
YES ☐	NO☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
YES ☐	NO☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
YES ☐	NO☐	**7. Do you have a diabetes or thyroid condition?**
YES ☐	NO☐	**8. Do you know of any other reason why you should not do physical activity?**

If you answered "Yes":

YES to one or more questions

A medical clearance form is required of all participants who answer 'yes' to any of the eight PAR-Q questions.

Note: Personal training staff reserve the right to require medical clearance from any client they feel may be at risk.

- Discuss with your personal doctor any conditions that may affect your exercise program.
- All precautions must be documented on the medical clearance form by your personal doctor.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such a cold or a fever - wait until you feel better; or
- If you are or may be pregnant - talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professionals.

Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability to persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME____

SIGNATURE____

DATE____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

CSEP SCPE

Health Canada Santé Canada

Appendix I. Participant consent form

College of Health
School of Sport and Exercise
Massey University
Private Bag 756
Wellington 6140

Review of Armed Offenders Squad (AOS) and Special Tactics Group (STG) fitness policies for the New Zealand Police.

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree/do not agree to the exercise tasks being image recorded.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name - printed ....

Appendix J. Letter of ethical approval - Phase Two

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

7 January 2014

James Dickie
School of Sport & Exercise
WELLINGTON

Dear James

Re: HEC: Southern A Application – 13/71
Review of Armed Offenders Squad and Special Tactics Group fitness policy for the New Zealand Police

Thank you for your letter dated 7 January 2014.

On behalf of the Massey University Human Ethics Committee: Southern A I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Dr Brian Finch, Chair
Massey University Human Ethics Committee: Southern A

cc Dr Sally Lark
School of Sport & Exercise
WELLINGTON

Dr James Faulkner
School of Sport & Exercise
WELLINGTON

Dr Matt Barnes
School of Sport & Exercise
PN621

Prof Stephen Stannard, HoS
School of Sport & Exercise
PN621

Massey University Human Ethics Committee
Accredited by the Health Research Council
Research Ethics Office

Massey University, Private Bag 11222, Palmerston North 4442, New Zealand T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz www.massey.ac.nz

Appendix K. Procedures for upper body electrode placements

Procedures for upper body electrode placements.

Muscle	Reference	Position	Location
Upper pec major	Bull, Ferreira & Vitti, 2011	Lying supine	2cm below the anterior border of the clavicle the longitudinal axis which crosses the middle point of the clavicle
Biceps brachii	SENIAM	Sitting on a chair with the elbow flexed at a right angle	On the line between the medial acromion and the fossa cubit at 1/3 from the fossa cubit.
Brachioradialis	Researcher	Sitting with elbow fully extended in front and in pronation	Muscle belly
Medial deltoid	SENIAM	Sitting in normal posture (scapula retraction, if stabilisers are weak)	Line from the acromion to the lateral epicondyle of the elbow (muscle belly)
Middle trap	SENIAM	Erect sitting, with the arms hanging	50 % between the medial border of the scapula and the spine, at the level of T3
Lower trap	SENIAM	Erect sitting, with the arms hanging	2/3 on the line from the trigonum spine to the 8th thoracic vertebra
Lat Dorsi	Hibbs et al., 2011; Se-Yeon Park & Won-gyu Yoo, 2013	Prone lying	4cm below the inferior tip of the scapula and midway between the spine and lateral edge of the torso.
Infraspinatus	Waite, 2010	Prone with arm abducted to 90° and arm is flexed over the edge of bench	Parallel to spine of scapula, approximately 4cm below, over the infra scapular fossa.

Appendix L. Procedures for core electrode placements

Procedures for placement of core electrodes.

Muscle	Reference	Position	Location
Rectus abdominis	Ekstrom et al., 2007; Hibbs et al., 2011; Marshall et al., 2011	Lying supine	3cm lateral to umbilicus and 2-5cm superior
External oblique	Ekstrom et al., 2007; Tong et al., 2013; Youdas et al., 2008	Lying supine	Midway between ASIS and rib cage
Internal oblique	Garcia-Vaquero et al., 2012; Youdas et al., 2008	Lying supine	Centre of triangle formed by inguial ligament, outer edge of rectus sheath and line from ASIS to umbilicus
Multifidus	SENIAM	Prone with the lumbar vertebral columns slightly flexed	A line from the posterior superior iliac spine to the interspace between L1 and L2, at the level of L5 spinous process (i.e. about 2 - 3 cm from the midline)
Erector spinae lumbar	Garcia-Vaquero et al., 2012; Juker et al., 1998; Lehman et al., 2005; Potvin et al., 1996	Prone with the lumbar vertebral columns slightly flexed	3cm lateral to the posterior spinous process at the level of L3
Erector spinae thoracic	Potvin et al., 1996; Vera-Garcia et al., 2010	Prone with the lumbar vertebral columns slightly flexed	4cm lateral to the posterior spinous process at the level of T9

Appendix M. Procedures for MVIC testing of upper body muscles

Procedures for MVIC testing of the upper body muscles associated with the rope pull-up, rope climb and ladder climb adapted from Hislop et al., (2014).

Muscle	Position	Test
Upper pec	**Participant –** Lying supine with elbow bent to 60° and arm in 60° abduction **Researcher –** Stand at side of shoulder to be tested. Hand used for resistance is contoured around the forearm just proximal to the wrist.	Participant attempts to move arm up and in across the body. Resistance is applied in a downward direction (towards floor) and outward (opposite to direction fibres). “Move your arm up and in”.
Biceps brachii	**Participant –** Short sitting with arms at side, forearm in supination. **Researcher –** Stand in front of participant towards test side. Hand giving resistance is contoured around forearm proximal to the wrist. The other hand applies counterforce by cupping the palm over the anterior superior surface of shoulder.	Participant flexes elbow through range of motion apply resistance at about 90° flexion. “Bend your elbow, hold it”.
Brachioradi alis	**Participant –** Short sitting with arms at side, forearm in neutral position. **Researcher –** Stand in front of participant towards test side. Hand giving resistance is contoured around forearm proximal to the wrist. The other hand applies counterforce by cupping the palm over the anterior superior surface of shoulder.	Participant flexes elbow through range of motion apply resistance at about 90° flexion. “Bend your elbow, hold it”.
Mid deltoid	**Participant –** Short sitting with arm at side and elbow slightly flexed **Researcher –** Stand behind patient. Hand giving resistance is contoured over arm just above elbow.	Participant abducts arm to 90°. “Lift your arm out to the side to shoulder level, hold it”.
Mid trap	**Participant –** Prone with shoulder at edge of table. Shoulder abducted to 90°, elbow is flexed to a right angle (alternatively elbow can be fully extended). **Researcher –** Stand at test side close to participants arm. Stabilise the contralateral scapular area to prevent trunk rotation. Place hand at distal end of humerus and provide resistance directly downwards toward floor (can apply resistance at wrist if needed).	Participant horizontally abducts arm and adducts scapular. “Lift your elbow towards the ceiling”.
Lower Trap	**Participant -** Lying prone with arm over head to about 145° of abduction (in line with fibres). Forearm is in neutral position with thumb pointing upwards. **Researcher –** Stand at test side, hand providing resistance is contoured over elbow, resistance to be applied towards floor.	Participant raises arm from the table to at least ear height and holds against resistance. “Raise your arm from the table as high as possible, hold it against the resistance”.
Lat dorsi	**Participant –** Prone with arms at sides and shoulder internally rotated (palm up). **Researcher –** Stand at test side. Hand used for resistance is contoured over posterior arm just above elbow.	Participant raises arm off the table, keeping the elbow straight. “Lift arm as high as possible and hold against resistance”.
Infraspinatu s	**Participant –** Prone with head turned towards test side. Shoulder abducted to 90° with arm fully supported on table, forearm hanging vertically over edge of table. **Researcher –** Stand at test side at level of participant’s waist. Two fingers of one hand are used to give resistance at the wrist. The other hand supports the elbow to provide some counter pressure at the end range.	Participant moves forearm upwards through external rotation. “Raise your arm to the level of the table, hold it”.

Appendix N. Procedures for MVIC testing of core muscles

Procedures for MVIC testing of the core musculature associated with the bridge test.

Muscle	**Reference**	**Test**
Rectus abdominis	Ekstrom, 2007; Garcia-Vaquero et al., 2012	Partial curl up with feet secured and resistance applied at the shoulders
Upper RA	Vera-Garcia et al., 2010	Lower trunk flexion – Subject attempts to flex the lower trunk in the sagittal plane while she is in a supine lying position with knees and hips both bent to 90°. Thorax was strapped down with a belt and legs were manually braced by the experimenter
External oblique	Ekstrom, 2007; Garcia-Vaquero et al., 2012; Lehman et al., 2005; Youdas et al., 2008	Subject performs an oblique curl up, attempting to move resisted shoulder toward the opposite knee
Internal Oblique	Vera-Garcia et al., 2010	Lower trunk bending – Subject maintained a side bridge position whilst maximally resisting downward pressure applied at the pelvis
Thoracic ES	Vera-Garcia et al., 2010	Upper trunk extension – Subject strapped in prone position with the torso horizontally cantilevered over the bench. They then attempt to extend the upper trunk in sagittal plane and retract the shoulders while manual resistance is applied at the shoulders
Lumbar ES	Vera-Garcia et al., 2010	Lower trunk extension – Subject attempts to extend the lower trunk and hips against manual resistance when in a prone position, with torso on bench and legs horizontally cantilevered over end of bench
Multifidus	Ekstrom et al., 2007; Lehman et al., 2005	Prone trunk extension to end range, with resistance applied at the upper thoracic area

Appendix O. Warm up protocol

Warm up protocol

Order	Exercise	Duration
1	Light jogging	60 seconds
2	Body weight squats	10 repetitions
3	Push ups	5 repetitions
4	Forward shoulder rolls	5 repetitions
5	Backward shoulder rolls	5 repetitions
6	Light jogging	30 seconds
7	Forward arm circles	10 repetitions
8	Backward arm circles	10 repetitions
9	Light jogging	15 seconds