EFFECT OF WALKING EXTRA DISTANCES

ON THE PERFORMANCE OF GRAZING DAIRY COWS

IN EARLY LACTATION

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ABSTRACT

Two groups, each of 13 Friesian cows in early lactation, were fed and managed identically throughout the experimental period of 4 weeks (13th September-10th October, 1993), except that the control group (CT) walked directly from the paddock to the milking shed and back to the paddock (average 1.5 km per day), whereas the walk group (WK) walked approximately 6 km more per day than the control group (total 7.5 km per day). During walking, all cows were moved at the average walking speed of 55 m/min. The aim of the study was to examine the effects of walking extra distances on the performance of grazing dairy cows in early lactation.

A common daily herbage allowance (30-40 kgDM/cow/day) was given to both groups grazed in the same paddock, on equal areas separated by an electric fence. Milk production and composition, somatic cell counts, liveweight and condition score, reproductive performance and grazing behaviour were measured and analysed.

Herbage intake was estimated directly using a rising plate pasture meter and indirectly using chromic oxide technique (slow release chromium capsules; CAPTEC NZ., Ltd). The average dry matter intakes, as assessed by the pasture meter, were similar for the CT and the WK group being 16.1 and 16.5 kgDM/cow/day, respectively.

Average daily yields of milk and milk solids for both groups were 25 litres/cow and 1.9 kg/cow, respectively. There were no significant differences in milk yields, milk composition, somatic cell counts (SCC), or changes in liveweight and condition score

between the two groups. However, the WK group did produce slightly less milk solids (by 2 to 3%), and had slightly higher SCC than the CT group. No adverse effects on reproductive performance of cows in the WK group were observed.

Although the WK group spent less time on the pasture by about 1.5 hour per day, there was no significant difference in time spent grazing (GT) between both groups. Nevertheless, the WK group spent significantly less time standing ($P<0.001$) per day than the CT group, mainly because of less time spent standing/ruminating.

The results show that high producing dairy cows in early lactation can walk horizontally (only a small hill was involved), at a comfortable walking speed, up to 7.5 km per day with no significant effects on milk production provided that pasture allowance is not restricted.

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CHAPTER 1 : INTRODUCTION

INTRODUCTION

Pastoral dairy farming in New Zealand is dependent upon grazing dairy cows on well-managed rye grass and clover pasture. One of the major activities involved inevitably with grazing is walking, especially on farms with a large area of land. Most dairy farms in New Zealand are relatively large herds with an average of 170 cows, and an average effective area of 70 hectares (Livestock Improvement, 1992). Also, evidence has shown that there is, in fact, a considerable trend in increasing farm size because the number of herds with more than 300 cows increased from 0.4% in 1970/71 to 6.5% in 1990/91. Hence, on larger dairy farms and even some smaller farms, cows are frequently required to walk several kilometres between the grazed paddock and the milking shed before and after each milking. A survey by Thomson and Barnes (1993) suggests that walking distances on these large herds vary from 2-7 km/milking. Therefore, it is important to know if the activity of walking has any effects on the cow's performance and the size of those effects when cows are required to walk long distances each day.

Although there appears to be little data about this topic, the activity of walking may have many effects on the cow such as strain on the udder and feet, increased body temperature, and increased energy expenditure. Even if the only effect of walking is to cause an increase in energy expenditure, then the effects on the herd's feed requirements and on milk production could possibly be significant on farms where the lactating cows have to walk several kilometres daily. Under practical situations in New Zealand, however, this aspect has received little attention by both researchers and farmers, and no increase in feed requirements is usually allowed for in herds having to walk long

distances. It is therefore considered to be important to study these effects so that the size of any effects can be taken into account in the overall planning of farms and their layout.

The present study was designed to examine the effect of walking long distance on the performance of grazing dairy cows including milk production and its composition, somatic cell counts, liveweight and condition score changes, and reproductive performance. The effects on voluntary feed consumption and on grazing behaviour were also investigated. The review also includes discussions of the effect of exercise on nutrient requirements and on substrate utilisation by contracting muscles which may, in turn, adversely affect the dairy cow's productivity.

CHAPTER 2 : REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 THE ENERGY COST OF WALKING

Little information is available in world literature on the energy cost of walking in cattle although it is obviously a significant contributor to the energy requirement of the grazing animal at pasture or on range land. The estimates made by ARC (1980) and some other workers (Brody, 1945; Ribeiro et al., 1977; King, 1983; Lawrence and Stibbards, 1990) suggested that the extra energy required above maintenance was about 2.0 J/kg liveweight/m for horizontal movement and 28.0 J/kg liveweight/m for vertical movement (Table 2.1).

Table 2.1 Published values for energy expenditure for walking in cattle.

Activity	Energy Cost (J/kgLW/m)	Species	References
Walking	1.9	Bos taurus	Brody (1945)
(horizontal)	2.0	Bos taurus	Ribeiro et al.(1977)
	0.5-2.8	Bos indicus	King (1983)
	2.0	Cattle	ARC (1980)
	2.1	Bos indicus	Lawrence & Stibbards (1990)
Walking	26.0	Bos taurus	Ribeiro et al.(1977)
(Vertical)	28.0	Cattle	ARC (1980)

Yousef and Maloiy (1985) suggested, from available data, that the metabolic cost of walking increases linearly with the speed of walking. The effect of speed on the energy cost of horizontal walking was well described by Ribeiro *et al.* (1977) who indicated that the cost was least at a speed of about 55 m/min, and appeared to increase slightly as speed increased from 60 to 100 m/min. A significant positive correlation between energy cost of horizontal walking and walking speed for cattle and buffaloes has also been reported by Lawrence and Stibbards (1990). These authors, however, suggested that energy cost of walking was not affected by speed within the range of 36 to 60 m/min. This is in agreement with Dijkman (1992) who studied the energy cost of walking in donkeys and found that energy cost of walking was not affected by speed within the range of 36 to 78 m/min, but gradient had a significant effect. Ribeiro *et al.* (1977) concluded that, for cattle moving at a comfortable walking speed (between 50 and 60 m/min), the energy cost of horizontal locomotion was about 2.0 J/kgLW/m, irrespective of body weight or plane of nutrition.

AAC (1990) suggested that the additional energy expenditure on walking by dairy cows brought in from pasture for milking is a minimum of 2.6 J/kg liveweight for each metre walked from and back to their pasture. According to this estimated value, the ME requirement for a 450 kg cow walked 1 km extra would be 1.2 MJ/day. In New Zealand conditions, the estimated M/D value for spring pasture (September-October) is 11.5 MJ/kgDM, and the ME requirement for lactation for a Friesian cow is assumed to be 4.8 MJ/kg milk (Holmes and Wilson, 1987). Using the above assumptions, the energy required for walking can, therefore, be expressed in terms of the energy required to produce milk which is equivalent to:

1 km horizontal walking = 0.1 kg DM or 0.25 kg milk

1 km vertical walking   = 1.1 kg DM or 2.6 kg milk

Thus, it is assumed that for each km extra distance walked a lactating cow must consume more feed dry matter in order to maintain its milk production, or otherwise its milk yield will be decreased approximately by 0.25 kg and 2.6 kg per km horizontal and vertical walking, respectively.

2.2 EFFECT OF EXERCISE ON VOLUNTARY FEED INTAKE

The regulation of voluntary feed intake in grazing ruminants is a complex system involving many factors including animal factors such as genotype, size, age, liveweight, and physiological state; feed and management factors such as digestibility, herbage species, herbage mass, herbage allowance, and supplementary feeding; and environmental factors such as climate and season (Meijs, 1981). However, a simplified view is to see limitations to voluntary feed intake operating through two main factors: metabolic control and physical control. Metabolic control is associated with factors which influence the animal's requirements for nutrients and its ability to metabolise absorbed nutrients whereas physical control is associated with rumen capacity, distention and the rate of disappearance of digesta from the rumen (Baile and Forbes, 1974; Bines, 1971; 1979; Campling, 1980). Under optimal conditions of diet and environment, viz. palatable and highly digestible diet, and minimal environmental stress, feed intake is more likely determined by the animal's energy demand (Campling, 1980; Weston, 1985a). This demand, in turn, is a function of genotype, physiological state, diet nutrient

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status and exercise. As exercise is one of the many factors influencing the animal metabolic requirements for nutrients, feed intake by animals performing extra work (or extra walking) would be expected to increase.

Published literature on the effect of exercise on feed intake is inconsistent. Some authors (Barton, 1987; Henning, 1987; Wanapat and Wachirapakorn, 1987; Bakrie *et al.* 1988; Bamualim and Ffoulkes, 1988; Pearson, 1990; Matthewman *et al.* 1993a) have found no increase, while others (Ffoulkes, 1986; Ffoulkes *et al.* 1987; Winugroho, 1988; Wachirapakorn and Wanapat, 1989; Bakrie *et al.* 1989; Pearson and Lawrence, 1992) have reported greater intake in working animals compared with non-working control animals.

Barton (1987) fed oxen on either urea-treated or untreated rice straw supplemented with 1 kg fresh grass over a 7-week working period and found that exercise did not increase feed intake. Henning (1987) failed to demonstrate increased feed intake or rumen-fill in sheep exercised on treadmills for up to 9 km/day, over 3 h/day for 14 days. Wanapat and Wachirapakorn (1987), studying water buffaloes in Thailand, found a slight but non-significant decrease in feed intake in walking buffaloes (at a speed of 52.5 m/min. during walking treatment for 2 h/d) as compared to the resting buffaloes. In Nepal, Pearson (1990) found that when oxen were exercised they consumed less feed and lost weight. This is in agreement with Matthewman *et al.* (1993a) who found that lactating Hereford-Friesian cows walking 10.6 km/day and given poor quality roughage, could not increase daily intake in the short term to meet energy requirements and that intake may even decrease when animals work. These authors

concluded that moderate levels of energy expenditure for work did not stimulate an increased intake of straw to meet the extra energy demands for walking, despite weight losses when animals walked. As would be the case, with low digestibility straw, voluntary feed intake may be mainly restricted by rumen fill. Moreover, food supplements of different composition designed to augment nutrients for the basal forage with different sources of carbohydrate or protein, did not affect the intake response of these animals during exercise (Matthewman *et al.* 1993a).

In contrast, Ffoulkes (1986) and Winugroho (1988) found an increased intake in working buffalo cows fed rice straw and fresh grass. Similarly, Ffoulkes *et al.* (1987) found that walking buffalos consumed 7% more poor quality roughage. These authors concluded from their work that if these were true effects of exercise then the point at which tissue building nutrients are utilised as energy sources for prolonged muscular activity will be delayed by the greater availability of nutrients from the diet when animals exercise or work. In a study on oxen in Costa Rica, Pearson and Lawrence (1992) found that although work caused an increase in feed intake, the increased intake occurred after the work period had ended.

In addition to metabolic and physical factors, Hodgson (1977) concluded that voluntary feed intake of grazing animals can also be influenced by behavioural factors. The amount of daily herbage intake (I) by grazing ruminants is determined by the time spent grazing per day (GT), the amount of herbage consumed per bite (IB) and the rate of biting per minute of grazing time (RB) (Allden and Whittaker, 1970). The time spent exercising or walking may reduce the time available for eating and hence affect feed

intake. Pearson (1990) considered that the reduced time available for feeding is likely to restrict intake in working animals offered bulky diets. However, Henning (1987) suggested that time spent working (or walking) may not interfere with feed intake by grazing animals.

2.3 EFFECT OF EXERCISE ON RUMEN FERMENTATION AND DIGESTION

Linked to the effect of exercise on feed intake is the effect on digestive functions. Significant improvements in diet digestibility have been reported by several authors (Ffoulkes, 1986; Ffoulkes *et al.* 1987; Winugroho, 1988), whereas many reported no differences (Kibet and Hansen, 1985; Soller *et al.* 1986; Bamualim and Ffoulkes, 1987; Henning, 1987; Wanapat and Wachirapakorn, 1987; Pearson, 1990).

Ffoulkes (1986) reported a 13% increase (P<0.05) in digestibility in working buffaloes which were fed to meet their energy requirements. Ffoulkes *et al.* (1987) found that walking buffaloes ate 7% more poor quality roughage (P<0.1) and that digestibility increased from 46.9 to 52.9% (p<0.05). Similarly, Winugroho (1988) reported an increase from 38% to 50% in digestibility in working buffaloes compared with non-working buffaloes. Kibet and Hansen (1985), however, found that rumen dry matter digestibility (DMD) was not influenced by exercise and distance walked. These authors reported the DMD values of 47%, 49% and 46% for steers walked 0, 1 and 10 km, respectively. Also, there is no indication that work and exercise affect digestion in the intestine.

It was suggested that exercise may act as a physical stimulus to the movement of digesta and may cause a mixing of rumen and gut contents, which may aid passage through the tract (Matthewman and Dijkman, 1993). Relatively light exercise may have a beneficial effect on digestive function by causing a greater mixing of the rumen contents, which may enhance microbial fermentation.

Another possible reason is that exercise may cause increases in body temperature (Bunyavejchewin *et al.* 1985; Wanapat and Wachirapakorn, 1987; Teleni *et al.* 1991). Such increases in body temperature are most likely to cause reduced gut motility and rate of passage of digesta (Young, 1982) and thus resulting in an increase in feed digestibility due to the longer retention time of feed in the rumen. In addition to this, on diets which are marginally or severely deficient in ruminally available nitrogen, digestibility could be increased from the increased transfer of plasma urea to the rumen of the working animal (Teleni *et al.* 1991). At higher levels of work and exercise, however, more adverse effects may be seen. It might be expected that higher levels of exercise would cause a shift of blood supply from the gut to muscles and peripheral tissues (Matthewman and Dijkman, 1993).

The available results are therefore inconclusive about the effect of exercise on digestibility and feed intake, with no available information about dairy cattle grazing on temperate pastures.

2.4 EFFECT OF EXERCISE ON BODY TEMPERATURE

Upadhyay and Madan (1985), studying bullocks under heavy work load during summer (28-39°C) in India, found that rectal temperature, respiration rate, and heart rate increased significantly after work. These authors suggested that an increased body temperature during heavy work was also influenced by the environmental conditions. Studies with water buffaloes in Thailand (Bunyavejchewin *et al.* 1985; Wanapat and Wachirapakom, 1987) also indicated that exercising buffaloes had relatively higher rectal temperatures compared with the resting buffaloes. Similarly, Chaiyabutr *et al.* (1983) reported that, after 4 hours working while exposed to direct sunlight, body temperatures of buffaloes rose every hour from an initial reading of 38.9°C to 39.2, 39.6, 40.2 and 40.4°C, respectively. A trial in Egypt also indicated that buffaloes working while exposed to the sun for 2 hours increased their body temperature by 1.3°C (NRC, 1981).

At high ambient temperatures, animals attempt to decrease their heat load by reducing feed intake (Young, 1982). Therefore, exercising animals with elevated body temperatures, resulting from heat of both metabolic and environmental origin, would also be expected to have reduced appetites. However, Upadhayay (1993) suggested that animals performing work at low ambient temperature showed a limited increase in body temperature.

2.5 EFFECT OF EXERCISE ON NUTRIENT REQUIREMENTS

The major factors affecting nutrient demands of ruminants are the different physiological states including maintenance, growth, pregnancy, lactation, and exercise. The energy required for exercise is influenced by several factors such as the intensity and duration of exercise, the environmental and physical conditions in which the exercise is performed, and the condition and body weight of animals (Bamualim and Kartiarso, 1985). In general, exercising animals will require an extra amount of energy for muscular work above that required for maintenance (ARC, 1980, 1984; AAC, 1990).

2.5.1 Metabolism of Active Muscle

Working muscles require a continuous supply of energy-yielding substrates to provide high energy phosphate (ATP) for sustained muscular activity (Leng, 1985; Pearson, 1985; Preston and Leng, 1987). At low levels of exercise, energy for contracting muscles is likely provided by the faster flow of blood nutrients absorbed directly from the diet, but as these become exhausted, fat (triglycerides), glycogen and protein in the body reserves are probably mobilised to meet continuous energy demand (Ffoulkes and Bamualim, 1989). Leng (1985) suggested that, although amino acids from body protein reserves may be mobilised, they are unlikely to be significant. The utilisation of energy-yielding substrates for generation of ATP for exercising muscles is demonstrated in Figure 1 (Teleni and Hogan, 1989).
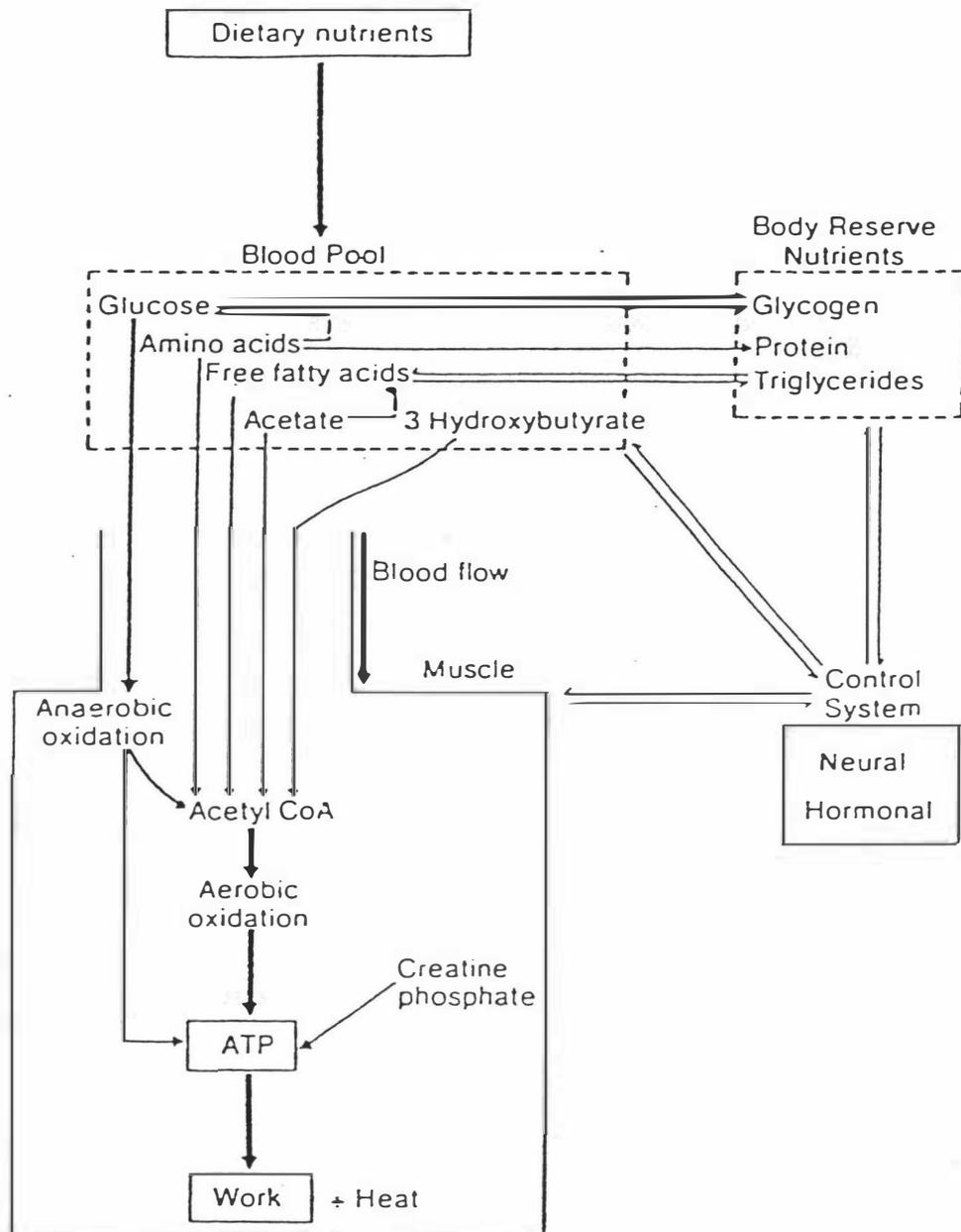
Figure 1 The utilisation of energy-yielding substrates for generation of ATP for

exercise (Teleni and Hogan, 1989).

2.5.2 Fat and Carbohydrate

It is obvious that when an animal exercises, it expends energy. The major class of nutrients required by the animal to supply fuel for its activity is therefore the energy-yielding nutrients. However, there are differences in the preferential requirement for each of these nutrients by the working muscle (Teleni, 1993). Studies with exercising sheep and cattle (Jarrett *et al.* 1976; Bird *et al.* 1981; Pethick, 1984) showed substantial increases in the uptake of glucose and free fatty acids by muscle during exercise. This suggests that both substrates are likely to be the energy-yielding nutrients preferred by the muscle for sustained exercise.

Judson *et al.* (1976) found the entry rate of glucose to increase two-fold and the rate of gluconeogenesis to increase 1.5 times in sheep walking at 5 km/hour, 0° incline. Increases in the entry rate of glucose have also been reported by Brockman (1979) and Brockman and Halvorson (1981; 1982). The increased glucose availability allows for a 3-4 fold increase in glucose uptake by skeletal muscle in walking sheep (Bird *et al.* 1981; Pethick *et al.* 1987). These studies have highlighted the importance of glucose as a substrate during exercise.

However, as the level of exercise increases, long-chain fatty acids become increasingly important substrates for ATP generation in contracting muscle and possibly contribute 80-90% of the ATP (Bird *et al.* 1981). During exercise, the release of the catecholamines and the reduction of insulin in circulating blood provide the hormonal milieu which is conducive to the hydrolysis of free fatty acids from fat depots (adipose

tissue) and their utilisation in muscle (Teleni, 1993). It might be suggested, therefore, that free fatty acids are the dominant oxidative substrate in working muscles.

Acetate is a major fuel for respiration in most tissues of the fed ruminant, including resting skeletal muscle (Bell, 1980). The uptake of acetate by muscle is dependent upon plane of nutrition. For example, low feed intake by the animal would result in a low uptake of acetate by muscle. Conversely, if the intake of feed was high, the uptake of acetate by muscle would be expected to increase. Exercise does not appear to change this pattern (Teleni and Hogan, 1989). Jarrett *et al.* (1976) found that the apparent importance of blood acetate as a fuel for exercise in resting muscle was reduced to an almost negligible level while net uptakes of free fatty acids and glucose increased substantially during exercise.

2.5.3 Protein

Protein is likely to have an important role in ATP production either through its direct oxidation and as a glucose precursor via gluconeogenesis or through its stimulatory role in digestion (Teleni and Hogan, 1989). The net release of amino acids from protein and the diversion of the energy-yielding nutrients to contracting muscle in exercising animals is likely to result in a nutrient imbalance of energy-yielding nutrients to amino acid ratio (Preston and Leng, 1987). This situation would lead to the utilisation of amino acids for energy-yielding purposes (ie. the catabolism of amino acids as direct energy sources or as glucose precursors). If part of the increased energy requirements for contracting muscles are met by protein sources, this would represent an increase in

protein requirements resulting from exercise. However, Pearson (1986) suggested that increases in daily amino acid requirements for muscle growth and development during work are likely to be small. Lawrence (1985), studied with oxen in Costa Rica, found that work had no significant influence on protein requirements. This author also suggested that, in situations where the animal has a surplus intake of ME, the rate of catabolism of amino acids might be low or even negligible. Nevertheless, it is likely that the rate of amino acid catabolism would probably be further increased if the animals are working under hot conditions (Graham 1985; Vercoe, 1969).

2.5.4 Minerals and Vitamins

Agarwal *et al.* (1982) reported a decrease in blood magnesium (and phosphorus in some animals) in working male buffaloes. Matthewman *et al.* (1993b) also found a decrease in blood magnesium and phosphorus concentrations in lactating Hereford-Friesian cows when animals walked. These reductions may be related to the increased use of both minerals in the processes associated with increased energy metabolism during exercise. Decreased blood phosphorus concentrations in exercising ruminants may represent an attempt to re-establish intracellular phosphate reserves or may result from increased carbohydrate metabolism in response to exercise (Codazza *et al.* 1974). Moreover, Teleni (1993) suggested that, as the intensity of exercise or work load increases, losses of sodium through excessive sweating in cattle working under hot conditions can be a problem, particularly in areas where the dietary sodium levels are marginal or deficient.

There seems to be no clear evidence that exercise significantly affects mineral and vitamin requirements and further research into this area is required.

2.6 EFFECT OF EXERCISE ON BODY WEIGHT

Loss of weight in working animals has been reported by several authors (Astatke et al. 1986; Ffoulkes, 1986; Winugroho, 1988). Astatke et al. (1986) found that both feed-restricted cattle and cattle fed to 100% of maintenance requirement lost weight when working for 5 hours daily over a 23-week period. This is in agreement with Ffoulkes (1986) and Winugroho (1988) who conducted the experiments with female buffaloes in Indonesia and found that these animals lost weight when they walked. These authors concluded that even on a restricted diet of rice straw and grass, non-exercising animals could maintain themselves and gain weight, but that working animals require a better diet to avoid weight loss. Bamualim and Ffoulkes (1987) found that although working non-pregnant female buffaloes were able to gain weight during working period, the growth rate of non-working animals was significantly higher (P<0.01) than that of working animals. A study in Thailand (Konanta et al. 1984 cited by Wanapat, 1985) also showed that body weight gains of non-working buffaloes were consistently higher than working buffaloes. The results from these findings indicate that nutrients absorbed from the digestive tract that would otherwise be destined for deposition in tissues are used as sources of energy for work, thus affecting the productivity of the working buffaloes in terms of slower growth compared to non-working buffaloes (Bamualim and Ffoulkes, 1988).

More recent studies with lactating Hereford-Friesian cows (Matthewman *et al.* 1993) indicated that cows gained weight when not exercised, but lost weight during the exercise period. However, these authors suggested that the resulting weight losses by exercising animals may be partly due to changes in gut fill during the exercise period.

2.7 EFFECT OF EXERCISE ON LACTATIONAL PERFORMANCE

It has been suggested that the increased nutrient demand of work for lactating cows may cause imbalance in the supply of glucose and precursors for milk synthesis (Leng, 1985). Studies with sheep (Bird *et al.* 1981; Pethick, 1984) also indicated that exercise increases the use of nutrients which are important for the support of lactation. Oldham and Friggens (1989) stated that exercise is one of the many sources of variability in lactational performance.

There appears to be very limited evidence on the effect of exercise on lactational performance, particularly in the dairy cows. Available evidence from published literature showed a variable effect of exercise on milk production (Rizwan-ul-Muqtadir *et al.* 1975; Goe, 1983; Lawrence, 1985; Reh and Host, 1985; Barton, 1987; Matthewman *et al.* 1989; 1993b; Thomson and Bames, 1993; Zerbini *et al.* 1993).

Goe (1983) reported that working cows may lose 10-20% of their milk yield during the work period. Similarly, Matthewman *et al.* (1989; 1993b) found that milk yield of exercised Hereford-Friesian cows, walked up to 9 km/day with an increase in elevation of 400 m, was depressed by between 7-14% when they were fed to meet

requirements for maintenance and lactation only. The levels of response demonstrated in these experiments were lower than those of Barton (1987) who worked animals continuously for 5 weeks and found a greater reduction (between 23 and 40%) in milk yield. Assessment from Bangladesh (Jabbar, 1983) also suggests a fall in milk production when cows are used for draught.

On the other hand, studies using lactating buffaloes in Pakistan (Rizwan-ul-Muqtadir *et al*. 1975) showed no reduction in daily milk yield during work. Research conducted in India, with working and non-working Red-Sindhi cows, also showed no significant difference in milk production over two lactation periods (Reh and Host, 1985). This is in agreement with Zerbini *et al*. (1993) who reported that work had no significant effect on milk yield or body weight change in crossbred dairy cows. In addition, Lawrence (1985) suggested that milk production of cows which were fed adequately did not drop when animals worked.

Recent experiments with grazing dairy cows in New Zealand (Thomson and Barnes, 1993) have shown that milk yield and protein yield were reduced significantly whereas somatic cell counts were increased and fat yield was relatively unaffected in grazing dairy cows walked extra distances (8 km daily). This is in agreement with Matthewman *et al*. (1993b) who found that exercise caused the decreases in milk yield, protein yield and lactose yield, but fat yield remained relatively constant. However, Rizwan-ul-Muqtadir *et al*. (1975) found no effect on milk composition when animals worked, even though milk yield declined.

2.8 EFFECT OF EXERCISE ON REPRODUCTION

Limited research has been conducted on the specific effects of exercise on reproductive performance. In draught animals, it is suggested that the additional stress of work imposed upon the animals working under hot conditions is most likely to reduce their reproductive performance (Jainudeen, 1985). An important aspect of reproduction that should be considered is the effect of exercise on ovarian function in female animals. Bamualim *et al.* (1987) indicated that work *per se* might affect ovarian activity directly. These authors showed that normal ovarian activity of swamp buffaloes was reduced when they worked.

On the other hand, Winugroho and Situmorang (1989) indicated that work *per se* was not a major factor influencing ovarian activity if energy reserves were adequate. They suggested that the combination of poor body condition and low average liveweight could be responsible for the high incidence of ovarian inactivity. In addition, Teleni *et al.* (1988) suggested that animals of reasonable body condition may stop cycling if they lost approximately 17% of their liveweight. Recent studies with crossbred dairy cows in Ethiopia (Agyemang *et al.* 1991; Zerbini *et al.* 1993) also indicated that work *per se* had little effect on reproductive performance.

2.9 OBJECTIVE OF THE STUDY

As previously reviewed, it is hypothesised that walking lactating dairy cows may have adverse effects on their productivity. However, under New Zealand conditions, this aspect has received little research attention although there have been some studies on this topic (Matthewman *et al*. 1993b; Thomson and Barnes, 1993), which were carried out in late or mid-lactation.

This present study was carried out to determine the effect of walking extra distances on the performance of grazing dairy cows in early lactation. The effects on herbage consumption, milk production and composition, body weight and condition score changes, reproductive performance and grazing behaviour were measured and investigated.

CHAPTER 3 : MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment was carried out at the Dairy Cattle Research Unit (DCRU), Massey University, during a period of 4 weeks (13th September to 10th October, 1993).

3.1 CLIMATIC ENVIRONMENT

Some climatic parameters during the experimental period are shown in Table 3.1.

Table 3.1 Climatological data during the experimental period

Month	Rainfall (mm/month)	Air temp.(°C)		Sunshine (hrs/day)
		Min.	Max.	
September	60.3	6.0	13.0	3.6
	(75)	(6.6)	(14.7)	(4.4)
October	60.0	8.7	17.1	5.7
	(88)	(8.3)	(16.6)	(5.1)

Source: AgResearch, Palmerston North.

Note: Data in the brackets are average 60 years data up to 1993.

3.2 ANIMALS AND TREATMENTS

3.2.1 Pre-experimental Period

Twenty six Friesian cows (3 to 8 year old) were used in the experiment. Before the start of the experiment, these cows were grazed generously with the main herd. Their milk production and somatic cell counts (SCC) were measured in the preliminary period to provide covariance adjustment data for the analysis of treatment effects.

3.2.2 Experimental Period

From information collected during the pre-experimental period, the selected cows were allocated into two groups, balanced for age and stage of lactation. Details of the cows used in the experiment are given in Table 3.2.

Table. 3.2 Data for the cows at the start of the experiment.

Mean values for:-	Control Group (CT)	Walk Group (WK)
Calving date	12/8/93	10/8/93
Days in milk	32±4	34±6
Milk yield (kg/cow/day)	24.5±4	25.6±3
Fat yield (kg/cow/day)	1.09±0.1	1.12±0.1
Protein yield (kg/cow/day)	0.85±0.07	0.89±0.05
Lactose yield (kg/cow/day)	1.24±0.1	1.30±0.1
Fat concentration (%)	4.5±0.3	4.4±0.2
Protein concentration (%)	3.5±0.2	3.5±0.2
Lactose concentration (%)	5.0±0.05	5.1±0.05
Liveweight (kg)	425±19	438±17
Condition score (units)	4.1±0.2	4.4±0.2

Note: Data shown were mean±standard error.

Cows in the two groups were fed and managed identically except that:

- The control group (CT) walked the minimum distance possible i.e. directly from the paddock to the milking shed and back to the paddock during each milking. The average walking distance for the control group was 1.5 km per day.

- The walk group (WK) was assigned to walk extra distances before and after each milking, throughout a four week experimental period. They walked approximately 6 km more per day than the control group. The average total distance walked for the walk group was 7.5 km per day.

Both groups were grazed in the same paddock, on equal areas separated by an electric fence, to ensure that they were offered similar pasture at the same level of feeding. A common daily herbage allowance (30-40 kgDM/cow/day) was given to both groups as one fresh area after the morning milking. Water was provided continuously to both groups in the paddock by using a movable water trough.

During walking, all cows were moved at the comfortable range of walking speed as suggested by Ribeiro *et al.* (1977). The average walking speed for both groups was 55 m/min (3.3 km/hour).

3.3 MEASUREMENTS

3.3.1 Pasture Measurements

Herbage mass (kgDM/ha) before and after grazing was measured by using a rising plate pasture meter (Holmes, 1974). The average amount of herbage consumed by the cows in each group was estimated as the difference between the pre-grazing herbage mass and the residual herbage mass, multiplied by the area allocated daily and divided by the number of cows grazing during that time.

Samples of herbage were collected pre-grazing, by hand plucking, to grazing height from each paddock. These samples were stored in the freezer for subsequent measurements of *in-vitro* digestibility and chemical analysis of the herbage. Samples for laboratory analysis were freeze-dried and ground to pass a 1 mm diameter sieve (Wiley Mill. USA). Dry matter was determined by heating at 80°C for 36 hours. Total nitrogen (N) was determined by Kjeldahl procedure, and *in-vitro* digestibility followed the method described by Roughan and Holland (1977).

Calculation of crude protein (CP) was made by using the commonly-accepted equation that:

$$CP = 6.25 \, N$$

where N = Nitrogen concentration in the dry matter (%).

3.3.2 Animal measurements

3.3.2.1 Voluntary Intake

Each of the twenty six cows in both groups were given a slow release chromium capsule (CAPTEC NZ., Ltd.) during the second week of the experimental period. Faecal samples were collected in the field from each cow during two consecutive 4 day periods, starting at day 6 after administration. The samples from each cow were bulked over each 4 day period and stored in plastic bottles which were kept in the freezer for later analysis of faecal chromium concentration.

Chromium concentration was measured as reported by Parker *et al.* (1989). Faecal output (FO) was calculated as:

$$\text{FO (kgDM/day)} = \frac{\text{Chromium release rate (g/day)}}{\text{Faecal chromium concentration (g/kgDM)}}$$

Dry matter intake (DMI) was then calculated from the following formula:

$$\text{DMI (kgDM/day)} = \frac{\text{FO (kgDM/day)}}{1 - \text{DMD (\%)}}$$

where DMD = dry matter digestibility of feed estimated by the *in-vitro* technique from the pre-grazing herbage samples collected by hand plucking.

3.3.2.2 Milk Production and Somatic Cell Counts

Throughout the experiment, the yield and composition (fat, protein and lactose) of milk produced by each cow in both groups were measured on two consecutive days per week, using Metatron Milk Meters (Westfalia) and a Milko Scan 140A Analyzer (A/S N Foss, Denmark). On the same days, milk samples were taken from each cow for a measurement of somatic cell counts (SCC) using a Fossomatic Fluoro-optical counter (A/S N Foss, Denmark).

3.3.2.3 Liveweight and Condition Score

All cows were weighed on two consecutive days prior to the start of the experiment and immediately after the experimental period. Body condition score for each cow was assessed at the same time as liveweight. The liveweights and condition scores of the two days were then averaged to represent liveweight and condition score for each cow at the start and the end of the experiment. The liveweight and condition score changes were defined as the difference between the start and the end of the experiment.

3.3.2.4 Grazing Behaviour

The grazing behaviours of each cow in both groups were recorded during a 48 hour period. The data were collected by watching the cows at intervals of 15 minutes over a period of 48 hours. The behaviours of the cows were categorized as follows:

Standing (ST)

Lying (LY)

Grazing (GR)

Ruminating (RU)

Standing/ruminating (SR)

Lying/ruminating (LR)

3.4 STATISTICAL ANALYSIS

All data were analysed using the Statistical Analysis System (SAS) computing package (SAS Institute, 1985).

Herbage mass (HM), residual herbage mass (RHM), herbage allowance (HA), dry matter intake (DMI), and activities of grazing behaviour (ST, LY, GR, RU, SR, LR) were analysed using analysis of variance (Steel and Torrie, 1986).

The model used to define the above data were:

$$y_{ij} = \mu + a_i + e_{ij}$$

where

y_{ij} = the observation on the jth individual exposed to the ith treatment. i=1,2; j=1,2,...,13.

μ = the unknown population mean

a_i = the effect of the ith treatment

e_{ij} = the random error associated with the jth individual exposed to the ith treatment. It is assumed that e_{ij} is normally distributed with mean 0 and variance σ^2.

Milk production data (yields of milk, milk fat, milk protein and lactose; milk fat %, protein % and lactose %) and somatic cell counts (SCC) were analysed using the repeated measurement analysis of covariance (Gill and Hafs, 1971; Morrison, 1976; Bryant and Gillings, 1985).

The analyses were based on the following model:

$$y_{pij} = \mu_p + a_{ip} + \beta_p x_{ij} + e_{pij}$$

where

y_{pij} = the observation on the jth individual measured in the pth week and belonging to the ith treatment

μ_p = the overall mean together with the effect of the pth week

a_{ip} = the effect of the ith treatment in the pth week

β_p = regression coefficient of y_{ij} on x_{ij} in the pth week

x_{ij} = the initial observation on the jth individual in the ith treatment

e_{pij} = random residual effects, which are assumed to be identically and independently distributed within the pth week, but there being covariance across weeks.

Final liveweight and body condition score were analysed using the analysis of covariance (Steel and Torrie, 1986) based on the following model:

$$y_{ij} = \mu + a_i + \beta x_{ij} + e_{ij}$$

where

y_{ij} = the observation on the jth individual exposed to the ith treatment

μ = the unknown population mean

a_i = the effect of the ith treatment

β = regression coefficient associated with x_{ij}

x_{ij} = the initial observation on the jth individual exposed to the ith treatment

e_{ij} = the random residual unique to y_{ij} which is assumed to be normally distributed with mean 0 and variance σ^2.

The following symbols are used in this thesis to determine the level of significance of differences between means.

***   Significant difference at the probability < 0.001

**   Significant difference at the probability < 0.01

*   Significant difference at the probability < 0.05

NS   Non-significant difference

CHAPTER 4 : RESULTS

4. RESULTS

4.1 CHEMICAL ANALYSIS OF THE HERBAGE

The results of chemical analyses of the herbage used in the experiment are given in Table 4.1. The values in each week were obtained from the analysis of pooled samples of pre-grazing herbage in that particular week. The apparently high values for crude protein percentage and *in-vitro* digestibilities throughout the experimental period were probably a reflection of the observed high proportion of legume in the leafy pasture. The digestibility analyses were repeated, and similar values were again recorded.

Table 4.1 Data for chemical analyses of the herbage used in the experiment.

	Week			
	1	2	3	4
CP (%)	24.1	25.2	25.6	26.2
DMD (%)	82.5	83.9	84.1	84.3
OMD (%)	86.9	88.4	88.9	89.2
DOMD (%)	76.5	77.6	77.7	78.2
Ash (%)	10.3	10.0	9.9	9.8

4.2 HERBAGE INTAKE

Mean values for herbage mass, residual herbage mass, herbage allowance and herbage intake of each treatment group during the experimental period, estimated by using the pasture meter, are presented in Table 4.2.

Table 4.2 Mean values for herbage measurements, allowance and apparent intake (measured by the pasture meter)

	CT	WK	SEM	Sig.
Herbage Mass (kgDM/ha)	2406	2435	90	NS
Residual HM (kgDM/ha)	1326	1340	68	NS
Herbage Allowance (KgDM/cow daily)	36	37	1.28	NS
Apparent Intake (kgDM/cow daily)	16.2	16.5	0.27	NS

SEM = standard error of the mean

Sig = significance of difference

As shown in Table 4.2, the levels of herbage mass before and after grazing (residual HM) were similar for both the CT and WK groups. The amounts of herbage allowance were not significantly different (P>0.05) between the two treatments. Mean values of apparent herbage intake for the CT and WK groups were very similar being 16.2 and 16.5 kgDM/cow/day, respectively.

Results of the intake assessment using the slow release chromium capsules (CAPTEC NZ., Ltd) were not entirely successful. Five capsules were found in the experimental paddocks and perhaps there were some other losses of capsules which were not found. From the analysis of chromium concentration in the faecal samples of 26 cows, the samples from only 13 cows (6 from the CT and 7 from the WK group) showed significant concentrations of chromium. Analysis of the results showed no significant treatment effect, and the DM intakes were 17.7 and 18.5 kgDM/cow/day for the 6 CT and the 7 WK cows, respectively.

4.3 ANIMAL PERFORMANCE

The pre-experimental data for the cows used in the experiment are given in the previous chapter (see Table 3.1). The results reported in the following Tables (Tables 4.3, 4.4, 4.5, 4.6 and 4.7) were adjusted using the initial statistics as covariates. Initial yields of milk, milk fat, milk protein and milk lactose , somatic cell counts, liveweight and condition score were used as covariates in the analysis of treatment effects.

4.3.1 Yields of Milk, Milk Fat, Milk Protein and Milk Lactose

There was no significant difference in yields of milk, milk fat, milk protein and milk lactose between the CT and WK groups throughout the experimental period. During the experiment, the cows in both groups produced an average of about 24-25 kg milk per day. Average daily yields (kg/cow) of milk, milk fat, milk protein and milk lactose were very similar over the 4 week period although there was a tendency for those yields in the walk group to be slightly lower than those in the control group.

Mean values for daily milk yield, fat yield, protein yield and lactose yield in each week for the two treatment groups are given in Table 4.3.

Table 4.3 Mean values for daily yields of milk, milk fat, milk protein, and lactose in each week (kg/cow).

	Week			
	1	2	3	4
Milk Yield				
CT	25.3	24.9	25.2	24.7
WK	25.0	24.1	24.5	24.1
SEM	0.46	0.51	0.58	0.67
Sig.	NS	NS	NS	NS
Fat Yield				
CT	1.13	1.09	1.06	1.03
WK	1.16	1.03	1.05	1.00
SEM	0.04	0.03	0.03	0.03
Sig.	NS	NS	NS	NS
Protein Yield				
CT	0.86	0.85	0.86	0.85
WK	0.85	0.81	0.83	0.83
SEM	0.02	0.02	0.02	0.02
Sig.	NS	NS	NS	NS
Lactose Yield				
CT	1.26	1.23	1.24	1.24
WK	1.25	1.19	1.21	1.19
SEM	0.03	0.03	0.03	0.04
Sig.	NS	NS	NS	NS

4.3.2 Milk Composition

As shown in Table 4.4, walking had no effect on the concentration of milk fat, milk protein and lactose over the 4 week experimental period.

Table 4.4 Mean values for the concentration of milk fat, milk protein and lactose.

	Week			
	1	2	3	4
Milk Fat (%)				
CT	4.50	4.42	4.20	4.20
WK	4.60	4.28	4.29	4.15
SEM	0.12	0.11	0.12	0.11
Sig.	NS	NS	NS	NS
Milk Protein (%)				
CT	3.40	3.43	3.41	3.44
WK	3.41	3.38	3.39	3.42
SEM	0.03	0.04	0.05	0.05
Sig.	NS	NS	NS	NS
Lactose (%)				
CT	5.00	4.96	4.94	4.94
WK	4.99	4.96	4.88	4.91
SEM	0.02	0.02	0.03	0.02
Sig.	NS	NS	NS	NS

4.3.3 Somatic Cell Counts

The results of somatic cell counts (SCC) showed no significant difference between the two treatment groups (Table 4.5). However, the WK group had consistently higher SCC than the CT group over the whole experimental period. Although there was a noticeable increase in SCC from the WK group, especially in the 3rd week, it should be noted that the standard error of the mean (SEM) was also very high. A case of clinical mastitis was recorded for one cow in the WK group during week 3 of the experiment, which was treated with antibiotic therapy.

Table 4.5 Mean values for somatic cell counts (000s/ml) for the two treatments.

	Week			
SCC	1	2	3	4
CT	78	93	126	123
WK	91	126	422	166
SEM	19	39	215	80
Sig.	NS	NS	NS	NS

4.3.4 Liveweight and Body Condition Score

The mean values for the initial liveweight, the final liveweight adjusted for initial weight, liveweight change, the initial condition score, the final condition score adjusted for initial score and condition score change are given in Table 4.6

There were no significant differences in the final liveweight and body condition score between the two groups. Both CT and WK groups gained weight and the gain in liveweight of the CT group tended to be higher than that of the WK group. However, there was no significant difference in liveweight gain between the CT and WK groups. Cows in the walk group lost body condition score whereas cows in the control group gained body condition score, but there was no significance difference in condition score change between both groups.

Table 4.6 Mean values for the final liveweight, final body condition score, liveweight change and condition score change for the two treatment groups.

	CT	WK	SEM	Sig.
Final LW (kg) (adjusted for initial LW)	441	440	3	NS
LW Change (g/day)	231	81	101	NS
Final CS (adjusted for initial CS)	4.3	4.2	0.1	NS
CS Change	0.04	-0.05	0.06	NS

4.3.5 Reproductive Performance

Data for some characteristics of reproductive performance of cows in the two groups are shown in Table 4.7.

Mean values for first mating date were similar for the two groups. Numbers of cows that showed signs of heat during the experimental period were also similar for both groups. Numbers of cows which conceived at first mating were 6 and 9 cows for the CT and WK, respectively. All cows in the WK group were pregnant whereas in the CT group only 10 cows were pregnant.

Table 4.7 Data for some characteristics of reproductive performance.

	CT	WK
Mean value for 1st mating date	12/11/93	9/11/93
No.of cows in heat (during experimental period)	9	8
No.of cows conceived at 1st mating	6	9
No.of pregnant cows	10	13

4.4 GRAZING BEHAVIOUR

The mean values for the time spent in various activities by the cows for the two treatments are presented in Table 4.7.

There were significant decreases in the time spent standing (P<0.001), ruminating (P<0.01), and standing/ruminating (P<0.001) per 24 hours in the cows subjected to walking extra distances. However, the time spent grazing, lying down and lying/ruminating showed no significant difference between the two treatments. It should also be noted that the WK cows spent less time on the pasture by about 1.5 hour per day.

Table 4.8 Mean values for the time spent in various activities by the cows for the two treatments (minutes per 24 hours).

Activities:	ST	LY	GR	RU	SR	LR
CT	730	560	539	471	140	332
WK	658	542	542	433	81	352
SEM	13	13	10	8	10	11
Sig.	***	NS	NS	**	***	NS

ST = Standing   GR = Grazing   SR = Standing/ruminating

LY = Lying   RU = Ruminating   LR = Lying/ruminating

CHAPTER 5 : DISCUSSION

5. DISCUSSION

5.1 EFFECT OF WALKING ON HERBAGE INTAKE

5.1.1 Herbage Mass and Herbage Allowance

Various techniques have been used to measure the herbage intake of grazing animals including sward methods such as sward cutting techniques and indirect animal methods such as indigestible marker techniques (Meijs, 1981). In the present study, the herbage DM intake was estimated directly by using a rising plate pasture meter and indirectly using the chromic oxide (slow release chromium capsules, CAPTEC NZ., Ltd) technique.

Herbage intake can be estimated by measuring the difference in herbage mass before and after grazing using the pasture meter (Holmes, 1974; Michell, 1982), which also provided information on herbage mass and herbage allowance. However, the major disadvantage of the technique was that it obtained only mean intake estimates for groups of animals. Michell (1982) suggested that use of the pasture meter for determining herbage intake and allowance has proved satisfactory with rotational grazing when there was almost complete utilisation of the pasture, although the estimation of herbage mass by such method was subject to an error of +200-300 kgDM/ha.

Mean values for pre-grazing herbage mass, residual herbage mass and herbage allowance, measured by the pasture meter, for the CT and WK groups (see Table 4.2)

were generally in the range of values in which DM intake was probably not restricted by non-nutritional sward characteristics (Combellas and Hodgson, 1979; Meijs, 1981; Holmes, 1987).

5.1.2 Herbage Intake

Weston (1985b) suggested that increased energy requirement by the animal would result in increased feed intake. This seems to be the case in lactating cows where the increased energy demand by the animals is associated with increased rumen capacity, increased rate of passage of digesta through the rumen, and increased intake of feed (Hutton, 1963; Weston and Cantle, 1982). In addition, Henning (1987) concluded that the increase in energy demand is not the major factor affecting voluntary intake by the animals. These authors suggested that the increase in roughage intake and rumen fill observed during lactation and cold stress are not necessarily caused by increased energy demand *per se* but might rather be a result of the action of hormones and metabolites associated with those specific physiological states. In general, grazing ruminants require substantially more energy for maintenance than stall fed animals and they also appear to compensate by eating more feed to meet their extra requirements of energy associated with grazing activities (Coop and Draw, 1963; ARC, 1980;1984; AAC, 1990). However, reports to date on the effect of exercise on feed intake are inconsistent (e.g. Barton, 1987; Henning, 1987; Wanapat and Wachirapakorn, 1987; Bakrie *et al.* 1988; 1989; Bamualim and Ffoulkes, 1988; Wachirapakorn and Wanapat, 1989; Pearson, 1990; Pearson and Lawrence, 1992).

Most experiments in which work or exercise caused a decrease in feed intake were carried out in tropical conditions where intake may have been restricted by low feed quality and high environmental temperatures (Collier and Beede, 1985). It appears that the major factor which could decrease feed intake in working animals is the increased heat load sustained by the working animals during work and for a few hours after work. For example, the body temperature of buffaloes could rise from 37.8°C to 41.0°C after three hours of work and not return to normal until after three hours of rest in the shade (Teleni *et al.* 1991). Longer working hours would obviously cause increased body temperatures for longer periods. Such increases in body temperature are likely to cause reduced rumen motility and rate of passage of digesta (Attebery and Johnson, 1969; Warren *et al.* 1974; Young, 1982) thus resulting in reduced feed intake. Therefore, despite the increased demand for nutrients as a result of work or exercise it is difficult to see a mechanism permitting a major increase in feed intake in working animals exposed to heat stress from work and from environment. Buffaloes, which have a much poorer heat dissipating capacity than cattle, may exhibit a reduction in feed intake under conditions in which cattle may not (Teleni, 1993). This probably explains the contradictions in the literature in which work may be associated with no change in feed intake (Bamualim and Ffoulkes, 1988), a reduction (Wanapat and Wachirapakorn, 1987; Pearson, 1990), or even an appreciable increase if the work periods are short (Wachirapakorn and Wanapat, 1989) or the animals are kept cool (Bakrie *et al.* 1989).

Unlike those studies discussed above, the present study involved with grazing dairy cows on high quality pastures in temperate condition, where it was unlikely that herbage intake by the animals will be primarily restricted by rumen fill or by environmental temperatures. Results of intake measurements in the present study showed no significant difference between the two treatment groups and mean values for DM

intake estimated by using the pasture meter were 16.2 and 16.5 kgDM/cow/day for the CT and WK group, respectively (see Table 4.2). Matthewman *et al.* (1993a) indicated that moderate levels of energy expenditure for exercise did not stimulate an increase in feed intake. A recent study with grazing dairy cows in New Zealand by Thomson and Bames (1993) also showed no significant difference in herbage intake between the normal walked cows (0.5 km/day) and cows subjected to walking extra distances (4 and 8 km/day). In contrast, light to medium work did increase voluntary intake, and digestible energy intake in growing horses fed nutritionally adequate diets (Orton *et al.* 1985).

It is also possible that the response in voluntary intake to the increased energy demand caused by walking exercise may have been offset by either (1) an interference of the exercise regime with grazing (or eating) time, (2) physiological effects of exercise which depressed appetite (i.e. exercise may cause increased body temperature). Although Pearson (1990) considered that the reduced time available for feeding is likely to restrict intake in exercising animals offered bulky diets, this seems unlikely to be the case in grazing animals (Henning, 1987). Smith (1961) found that cattle grazing for 7.5 hours/day were able to maintain the same intake as those grazing 10 hours/day. Smith suggested that cattle attempted to overcome the disadvantage of limited grazing time by increasing the rate of forage intake. In fact, it was shown in the present study that mean values for the time spent grazing (GT) were similar (about 9 hours/day for both groups; Table 4.7), even though the WK group spent less time in the grazed paddock by about 1.5 hours/day than the CT group. The similar time spent grazing for the CT and WK groups indicates that herbage intake should also have been similar in both groups which

is in agreement with the results shown in Table 4.1.

The body temperature of the cows were not measured in the present study. However, Upadhayay (1993) suggested that animals performing exercise at low ambient temperature showed a limited increase in body temperature. It is therefore unlikely, in the present study, that the intake was restricted by increased body temperature resulting from exercise. The results of studies involving walking exercise by mice (Baile *et al.* 1971), cattle (Coop and Drew, 1963) and humans (Durnin, 1985) indicated that it is also unlikely that the level of exercise used in the present study would have resulted in physiological stresses severe enough to lower intake.

From the above discussion, it can be concluded that the differences in intake response to the increased energy demand for exercise is not well understood. The likely explanation for this is: the increased energy demand *per se* is not the major factor in increasing voluntary feed intake by ruminants (Henning, 1987), and the extent to which the animal responds may be determined by the level of exercise performing by the animal. In fact, in the present experiment, the extra energy required by cows in the WK group was about 7 MJ/day (see Table 5.1) - so only a small increase in DM intake would be expected.

5.2 EFFECT OF WALKING ON ANIMAL PERFORMANCE

5.2.1 Milk Production and Composition

The prime objective of the present study was to examine the effect of walking extra distances on animal performance. Results obtained from the present study showed no significant difference in milk yield between the CT and WK groups. Cows in both groups produced similar daily milk yield of average about 25 litres/cow over the experimental period of 4 weeks (Table 4.2).

The concentrations of milk fat, milk protein and lactose were similar for both groups (Table 4.3), therefore the yield of these milk constituents were also similar and showed no significant difference between the two groups. However, mean values for the yields of milk, milk protein and lactose of the WK group were slightly lower (2-3%) than that of the CT group over the whole experimental period.

The results obtained from the present experiment were different from those reported from the recent experiments by Matthewman *et al.* (1989; 1993b) and Thomson and Barnes (1993). Matthewman *et al.* (1989; 1993b) found that walking exercise caused significant reductions in the yields of milk, protein and lactose, but not in the yield of milk fat. Similarly, the recent experiment conducted at Taranaki Agricultural Research Station by Thomson and Barnes (1993) showed that yields of milk and milk protein were significantly decreased by grazing dairy cows walked extra distances whereas fat yield was unaffected. However, it should also be noted that in the experiments

conducted by Matthewman *et al.* (1989; 1993b) and Thomson and Barnes (1993) the walking distances were greater and involving some hills of 40 m elevation whereas in the present study the animals were walked on a relatively flat plain. Although those authors (Matthewman *et al.* 1989; 1993b; Thomson and Barnes, 1993) reported decreases in milk yields by the animals subjected to walking extra distances, their results suggested that these reductions in lactational performance with walking exercise may be transitory. In the experiment conducted by Thomson and Barnes (1993), those adverse effects on milk yield and protein yield were only significant in one week of the 3 weeks monitoring period. Similarly, the decrease in milk yield became smaller in successive walking weeks in the study of Matthewman *et al.* (1993b). The reduced effect in subsequent weeks may result from increased fitness and a lower energy expenditure for pulmonary and vascular activity (Matthewman *et al.* 1993b). This explanation is supported by the work of Hays *et al.* (1978) who found that when trained animals worked, their heart rate, respiratory rate and rectal temperature were lower than that of untrained animals.

It has been suggested that exercise increases the use of nutrients which are important for the support of lactation (Bird *et al.* 1981; Jarrett *et al.* 1976; Pethick, 1984; Pethick *et al.* 1987). Studies with exercising sheep and cattle showed substantial increases in the uptake of glucose and free fatty acids by muscle during exercise, suggesting that both substrates are likely to be energy-yielding nutrients preferred by the contracting muscle. Matthewman *et al.* (1993b) showed a significant decrease in blood glucose concentration by the lactating cows subjected to walking extra distances. The lactating animal needs glucose not only to supply the brain and other tissues with fuel

but also as precursor for lactose synthesis (Kuhn, 1983). The rate of lactose synthesis and secretion by the mammary gland is the major determinant of milk volume. Annison (1983) suggested that at least 85% of the lactose carbon came from glucose, and lactose production in the udder could use as much as 60-85% of total glucose entry rate. In addition, the demands for glucose imposed by lactation include requirements for citrate and glycerol synthesis and for generation of at least part of the reducing equivalents used in *de novo* fatty acid synthesis (Annison, 1983). Therefore, the availability of glucose is critical for milk output.

In ruminant animals, over 90% of glucose may be produced by gluconeogenesis in the liver (Vernon and Peaker, 1983) because the main metabolites absorbed from the rumen are volatile fatty acids (acetate, propionate and butyrate) and only small amount of glucose absorbed from the lower gut. The precursors for gluconeogenesis include propionate, amino acids, lactate and glycerol but under normal feeding conditions and with high milk production it is likely that propionate is the major precursor (Bauman and Elliot, 1983).

Although blood metabolite concentrations were not measured in the present study, the above discussion suggests that the availability of glucose and glucose precursors were sufficient to support the demands for milk production and walking exercise. A slight reduction (not significant) in milk yield and lactose yield observed in the present study probably suggests that if the intensity of the exercise had been greater, then the increased demand for glucose to provide energy for contracting muscles would

have caused a significant decrease in milk yield by walking animals.

Teleni and Hogan (1989), however, suggested that at normal walking speed and low level of exercise it is likely that the dominant ATP-generating pathway would be aerobic oxidation (see Figure 1). Teleni (1993) indicated that the release of the catecholamines and the reduction of insulin in circulating blood during exercise may provide the hormonal milieu which is conducive to the hydrolysis of triglycerides to free fatty acids from fat depots and their utilisation in muscles. These orchestrated events would most probably ensure the dominant role of free fatty acids in energy supply to contracting muscles and the need to conserve glucose for milk production in lactating ruminants. Moreover, Teleni and Hogan (1989) suggested that the increased glucose entry rate in lactating animals subjected to exercise might be accounted for by the lactating mammary gland rather than by muscles. If this is the case then the availability of glucose for the lactating mammary gland of exercising cattle might not be the problem that it is purported to be (e.g. Matthewman *et al.*, 1989; 1993b).

The absence of any significant difference in milk fat yield in the present study was similar to those studies by Matthewman *et al.* (1989; 1993b) and Thomson and Barnes (1993). This may be due to substantial fatty acid mobilisation from body fat reserves, particularly in early lactation, which can provide an adequate supply of energy and metabolites for both exercise and milk fat synthesis. As a consequence, no reduction in milk fat concentration and hence milk fat yield could be observed. In the present study, the walked cows did appear to lose slightly body condition score at the end of the experiment (Table 4.6).

Also, milk protein yields in the present study were not significantly depressed by walking exercise. Pearson (1986) suggested that protein or amino acids do not appear to be utilised by exercising muscles to any extent. Lawrence (1985) also suggested that, in situations where the animal has a surplus intake of ME, the rate of amino acid catabolism to provide energy for contracting muscles might be low or even negligible. As the ME intake by walking animals in the present study appears to be sufficient, thus the protein concentration stayed relatively unchanged and as milk yield was not significantly affected, so the yield of milk protein was relatively unaffected.

Although results in the present study suggest that walking extra distances had no deleterious effect on milk production, the study was carried out with cows offered plenty of high quality pasture. In other situations where the supply of pasture is limited (i.e. in a cold, wet spring in New Zealand) or the quality of pasture is poor (i.e. under tropical conditions), the size of the effects may be greater, particularly under tropical conditions where walking exercise may impose more stress on cows, for example due to increased body temperatures. In those situations it is likely that the supply of energy and essential nutrients for supporting lactation will be inadequate and this will lead to larger adverse effects on lactational performance as a result of competitions for nutrient energy demands between exercise and lactation.

From the preceding discussions it is clear that in experiments where differences in milk production were reported, the difference was probably due to differences in availability of nutrients. If there were sufficient nutrients, no reduction in milk yields should be expected. It can be concluded that under temperate condition the effect of

walking on milk production is directly through competition for nutrients by contracting muscles and the lactating mammary gland. Any situation that intensifies this competition is likely to result in a reduction in milk production. There are no data available on the role of exercising muscles in the utilisation of substrates in lactating ruminants and further studies are certainly required in this important area.

5.2.2 Liveweight and Body Condition Score

In general, high producing cows which are fed generously tend to lose their liveweight in the first few weeks after calving and then to gain weight slowly. Results from the present study, however, showed that cows in both the CT and WK groups gained weight. Although the difference in liveweight gain between the two groups was not significant, the CT group tended to gain slightly more weight than the WK group. Cows in the CT group gained on average 150 g/day (Table 4.6) more than the WK group.

Results of the CS change showed that cows in the WK group tended to lose CS where as cows in the CT group tended to gain CS. The difference in CS change over the experimental period of 4 weeks between the two groups was approximately 0.1 CS and was not significant (Table 4.6). If it is assumed that 1 CS of Friesian cows is equivalent to 35 kg liveweight, then the difference in liveweight change between the two groups as calculated from the CS change would be 125 g/day which is similar to the measured difference in liveweight change. This difference in liveweight change between the CT and WK groups, although not significant, may be a reflection of the price that

cows in the WK group have to pay for the extra energy expenditure for walking. It can be tentatively concluded that part of the dietary nutrients absorbed from the digestive tract may be utilised by the contracting muscles instead of being used to synthesise body tissues.

5.2.3 Calculation for Energy Balance

Theoretical calculations based on liveweight, change in liveweight and milk production (Table 5.1) show that the total ME requirements for cows in the CT and WK groups were similar being 189 MJ/cow/day. Cows in the WK group spent more energy for the extra distance walked (about 7 MJ/cow/day), which is the same as the sum of the smaller amounts of energy required for milk and liveweight gain (Table 5.1).

Estimation of ME intake (plate meter) shows that cows in the WK group consumed sufficient energy from feed to meet their total energy requirements including the extra energy demand for walking (Table 5.1). This may be the reason that no significant differences in milk production and changes in liveweight and condition score were observed in the present study. It is therefore probable that when the ME intake become more restricted or there is a shortage for energy demands, the reductions in milk output and change in liveweight may well reach significant. In early lactation when peak intake normally lags behind peak milk yield and body reserves are mobilised to support lactation more severe reductions in cow's body weight would be expected. However, It should also be noted that although the difference in milk yield and in liveweight gain between the two treatment groups were not significant, cows in the walk group required

about 7 MJ ME less per day for milk and liveweight gain which was equal to extra energy required for longer distance walked (Table 5.1).

Table 5.1 Calculated energy balance for the two treatment groups.

	CT	WK
Average DM intake (kgDM/cow/day)	16.2	16.5
Estimated ME intake (MJ/day)[a]	186	190
ME for Maintenance (MJ/day)[b]	58	58
ME for LW gain (MJ/day)[c]	9	4
ME for milk (MJ/day)[d]	120	118
ME for walking (MJ/day)[e]	2	9
Total Energy Requirement (MJ/day)	189	189

Assuming that:

a   M/D value for spring pasture = 11.5 MJ ME/kgDM

b   ME maintenance = 0.60 MJ/kgLW$^{0.75}$ per day

c   ME gain = 38.5 MJ/kg LW gain

d   ME lactation = 4.8 MJ/kg milk

(a,b,c,d - Holmes and Wilson, 1987)

e   ME for 1 km horizontal walk = 0.0026 MJ/kg LW (AAC, 1990)

5.2.4 Reproductive Performance

As shown in Table 4.7, although the information can not be subjected to statistical analysis, it is obvious that walking, in this short-term present study, had no adverse effect on reproduction and fertility. All cows in the WK group were pregnant and of these 9 cows conceived at first mating whereas in the CT group only 10 cows were pregnant and 6 cows conceived at first mating.

The numbers of cows that showed signs of heat during the experimental period of 4 weeks were similar between the two groups. This suggests that ovarian function was not affected by walking activity, in agreement with Winugroho and Situmorang (1989) who suggested that exercise *per se* was not a major factor influencing ovarian activity if energy reserves were adequate.

Results of CS change from Table 4.6 suggest that cows in the WK group tended to lose their condition score during walking. If this is the case, extra distance walked for a longer period of several months might cause deleterious effects on the cow's reproduction as a result of real weight losses. For example, It was suggested that loss of approximately 17% of liveweight was detrimental to reproduction of cattle with reasonable body condition (Teleni *et al.* 1988). Winugroho and Situmorang (1989) also suggested that the combination of poor body condition and low average liveweight could be responsible for a high incidence of ovarian inactivity.

In addition, Matthewman *et al.* (1993b) reported that there was a decrease in blood magnesium and phosphorus in cows which walked extra distances, effects which might be associated with poor fertility, disturbed oestrus cycle and delayed conception (Holmes and Wilson,1987).

5.3 EFFECT OF WALKING ON SOMATIC CELL COUNTS

Somatic cell counts were not significantly affected by walking in the present study. However, cows in the WK group tended to have higher somatic cell counts than cows in the CT group (Table 4.5). The high somatic cell counts in the WK group in week 3 of the experiment were caused by the incidence of clinical mastitis in one cow in the WK group.

On the other hand, Thomson and Barnes (1993) found a significant increase in somatic cell counts in cows subjected to extra distance walked. These effects, however, were only significant in one week of a two week monitoring period and it can not be assumed the effects observed in the study by Thomson and Barnes (1993) are repeatable. Nevertheless, these authors suggested that in herds with high somatic cell counts (i.e. greater than 200,000), penalties could possibly result on days cows walked extra distances.

5.4 GRAZING BEHAVIOUR

It is apparent that walking distance had no effect on time spent grazing although cows in the WK group spent less time in the grazed paddocks by about 1.5 h/day. Time spent grazing was similar for both group being about 9 h/24 hours (Table 4.8) which is in the normal range (Stobbs and Minson,1983) suggesting that pasture on offer was not restricted.

Cows in the WK group spent significantly less time standing ($P < 0.001$), ruminating ($P < 0.01$) and standing/ruminating ($P < 0.001$) per 24 hours than cows in the CT group (Table 4.8). This probably suggests that cows in the WK group try to compensate for the extra energy expenditure for walking by reduce the activity of standing and ruminating. It is also probable that walking activity may have a beneficial effect on digestive function by causing a greater mixing of the rumen contents (Matthewman and Dijkman, 1993) which may enhance microbial fermentation in the rumen and hence leading to reduced rumination time.

5.5 ANIMAL HEALTH

There was no record of animal health problems in the present study except that one cow in the WK group had clinical signs of mastitis which was probably not caused directly by walking extra distances.

In fact, at the start of the experiment two of the 15 cows in the WK group had to be removed because of signs of lameness which was caused by one part of the walking track (race) which had a very stony surface. This part of the race was upgraded by covering it with saw dust and further no lameness was observed in any of the treatment groups.

Lameness is considered to be among the most important health problems in dairy production. It has a negative impact on feed intake, milk production, body condition and expression of oestrus may be reduced (Webster, 1987). Lameness may cause an average loss in income per farm of 1% due to reduced milk production in lame cows (Bridges, 1985). Dewes (1978) suggested that the incidence of lameness was attributed to walking long distances in wet conditions and where abrasive materials had accumulated on concrete races and holding yards. Chesterton *et al.* (1989), however, suggested that distance walked was not a major factor contributing to lameness but other factors associated with walking such as the average level of race maintenance and the patience shown by farmers when driving cows were probably more important. These authors also suggested that lameness appears to be a greater problem in housed than in grazing animals.

It is clear from preceding discussions that the magnitude of the effect of walking long distances on the performance of grazing cows is also dependent upon the characteristics of the walking track. If the track walked is stony, wet or muddy it is probable that the size of the negative effects on cow's performance would be greater, due to increased lameness.

CHAPTER 6 : CONCLUSION

6. CONCLUSION

Walking extra distances, in the present study, had no significant effects on cow's productivity. Yield of milk, milk solids, somatic cell count and liveweight and body condition score were not significantly depressed by walking treatment. However, animals which walked the extra distance did produce slightly less milk solids by about 2 to 3 % than the normal walk animals. The average milk production of cows in the two treatment groups was similar, being about 25 litres milk per day and 1.9 kg milk solids (yield of milk fat + milk protein) per day during the experiment. No adverse effects on reproduction of cows in the walking treatment were apparent. Cows in the walk group tended to have higher somatic cell counts than cows in the control group, although the difference was not significant.

Time spent grazing per 24 hours was not affected by walking regime, although cows in the walk group spent less time in the grazed paddock by about 1.5 hours per day than cows in the control group. Mean grazing time was about 9 hours per 24 hours for both groups and there was no significant difference in herbage intake between the two groups. Cows in the walk group, however, spent significantly less time standing, mainly because of less time standing/ruminating.

Although evidence from the present study suggests that there is little effect of walking on a relatively flat farm in New Zealand conditions, this may not be the case in a more stressful tropical environment and further studies are required under these conditions. Other possibilities for further research are the possible effects of walking on

more hilly farms, on lactational and reproductive performance over the whole lactation. These possibilities warrant investigations because there was a tendency, in the present study, for cow's condition score to decrease although the difference was not significant in the short term. However, this difference may have reached significance over a period of several months.

It can be concluded, from the present study, that high producing cows in early lactation can walk on a relatively flat farm up to 7.5 km/day, at a comfortable speed, with no significant effects on lactational and reproductive performance.

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