AN ANALYSIS OF THE IMPACT FORCES OF DIFFERENT MODES OF EXERCISE AS A CAUSAL FACTOR TO THE LOW BONE MINERAL DENSITY IN JOCKEYS

Sarah Jane Cullen[1], Giles Warrington[1], Eimear Dolan[1] and Kieran Moran[1]

Dublin City University, Dublin, Ireland[1]

The purpose of this study was to investigate the forces placed on the lower limbs of jockeys during riding and to determine whether these were comparable to the impact forces associated with traditional weight bearing activities such as walking and running. Evaluation of these forces will allow isolation of the key causes of the previously reported high incidence of low bone mineral density (BMD) associated with this population and indicate as to whether a lack of weight bearing exercise is a causative factor in this phenomenon. Eight apprentice jockeys completed 6 different activities including walking, running and riding (walk, trot, canter, gallop), where accelerometry data was collected to determine the amount of impact loading applied to the lower limbs. The impact accelerations of the lower limbs in horse riding were significantly lower than those seen in running ($p<0.05$). An individual walking appears to have no significant lower limb acceleration difference compared to trotting on a horse ($p<0.05$). However lower limb accelerations during walking are significantly higher to walking on a horse, and lower to cantering and galloping. The relatively non-weight bearing nature of the different riding trials compared to running suggests that jockeys may not receive adequate loading required to gain a sufficient osteogenic effect in order to optimise and maintain adequate BMD levels. Further research is required to validate the finding that, the lack of sufficient loading is a potential contributory factor to the low BMD observed in this population.

KEY WORDS: jockey, bone, musculoskeletal loading

INTRODUCTION: Osteoporosis, which is characterised by low bone mass and deterioration of bone tissue, is normally associated with an aging population and is most prevalent in post-menopausal (Reginster et al., 2006). More recently, it has been reported that professional male jockeys have abnormally low levels of mineralised bone tissue in a given area (BMD) compared to age and size matched subjects (Warrington et al., 2006, 2009). This high incidence of a low BMD observed in jockeys is of particular concern, in the context of the high incidence of falls and fractures recorded in horse racing (McCrory et al., 2006). To date, the primary causative factors which explain this pattern of low BMD in jockeys has not been determined. It has been suggested that chronic energy deficit due to restricted dietary intake, in order to make the strict weight requirements necessary to compete, may affect normal bone formation in jockeys (Leydon et al., 2002). Lack of appropriate weight bearing exercise is another modifiable risk factor which affects the formation of bones (Welton et al., 1994). The loading nature of horse racing has not yet been established, although it has been suggested that horse riding may not provide a sufficient osteogenic stimulus (Alfredson et al., 1998). The purpose of this study was to evaluate the forces placed on the lower limbs of the horse racing jockey during riding and compare this with data from traditional weight bearing activities.

METHODS:

Data Collection: Eight apprentice jockeys participated in this study (age 17$\pm$1 yrs; height 1.66 $\pm$0.11 m; body mass 57.04 $\pm$6.9 kg). Each subject was instrumented with 2 lightweight tri axial wireless accelerometers (Crossbow, type CXL100HF3, sensitivity 10 mVG, and range $\pm$100 g), attached to the lateral side of the tibial tuberosity and the base of the lumbar vertebrae (L4). These chosen positions provided a bony prominence for good contact to be achieved, with minimal interference from the riding boot, saddle, horse or any clothing. Accelerometers were aligned along the longitudinal axis of both the tibia and spine whilst subjects were standing. Measurements from the base of the foot to the sensor were recorded for each subject; ensuring correct replacement of the sensor. Subjects completed

6 different trials, in a random order, involving walking, running and riding (walk, trot, canter and gallop). The walking and running trials were completed inside the gymnasium with the cones set up as in the diagram on the wooden floors (Figure 1). Subjects wore their own training shoes. Each subject was instructed to move at a constant pace, aiming to pass a cone by the time a whistle signalled. For walking, the whistle signalled every 6secs ensuring an average walking speed of 6 km/h (1.67 m/s); for running every 3 s for an average running speed of 12 km/h (3.33 m/s).

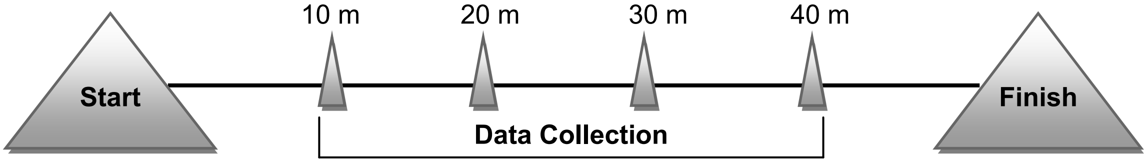

Figure 1: Apparatus used for the walking and running trial

The riding trials were completed in the indoor training arena with the test set up as in the diagram (Figure 2). Subjects wore their own riding boots and two different horses of the same training level were used. Moving clockwise around the arena, each subject was instructed to complete the 4 different gaits of locomotion on the horse (walk, trot, canter, and gallop), adjusting to the selected gait on arrival to the black cone.

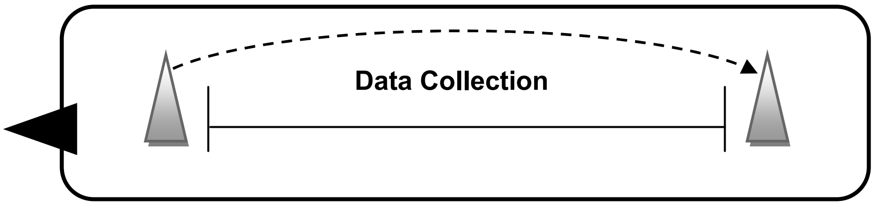

Figure 2: Apparatus used for the riding trial

Data Analysis: For this study, attention was focused on the vertical axis (Y), the direction of the shock waves transmitted vertically up through the bones. Five complete strikes were analysed for all conditions and all subjects. As a result, an average value was gathered for the accelerations applied to the tibia and the corresponding lower back value which was then used for statistical analysis (SPSS 16.0 for windows). Descriptive statistics were found for each dependent variable for each task; statistics included means and standard deviations. One way repeated measures ANOVA was performed on each of the group means to establish if a significant difference exists ($p \le 0.05$) in the impact loading placed on the lower limbs of the body among the different tasks. A pair wise comparison identified the location of the significant differences ($p \le 0.05$).

RESULTS: Acceleration magnitudes for both the lower leg and lower back were dependent on the mode of activity undertaken (Table 1).

Table 1: Impact Accelerations during the Different Activities

Activity	Lower Leg Acceleration (g)	Lower Back Acceleration (g)
Walk	2.25 ± 0.82^{e}	1.04 ± 0.14^{f}
Run	13.18 ± 6.99^{b}	3.54 ± 1.04^{c}
Walk – Horse Ride	$1.21 \pm 0.52^{a\ e}$	$0.68 \pm 0.33^{b\ f}$
Trot – Horse Ride	2.94 ± 1.12^{e}	0.75 ± 0.42^{f}
Canter – Horse Ride	$2.96 \pm 0.55^{a\ e}$	$1.64 \pm 0.58^{a\ e}$
Gallop – Horse Ride	$3.64 \pm 0.82^{b\ e}$	$1.79 \pm 0.69^{a\ d}$

Data presented as mean ± SD, $^{a}p \le 0.05$; different to walking, $^{b}p \le 0.01$; different to walking, $^{c}p \le 0.001$; different to walking, $^{d}p \le 0.05$; different to running, $^{e}p \le 0.01$; different to running, $^{f}p \le 0.001$; different to running.

The effect of the individual activities on lower leg and back impact accelerations are shown (Figures 3 and 4).

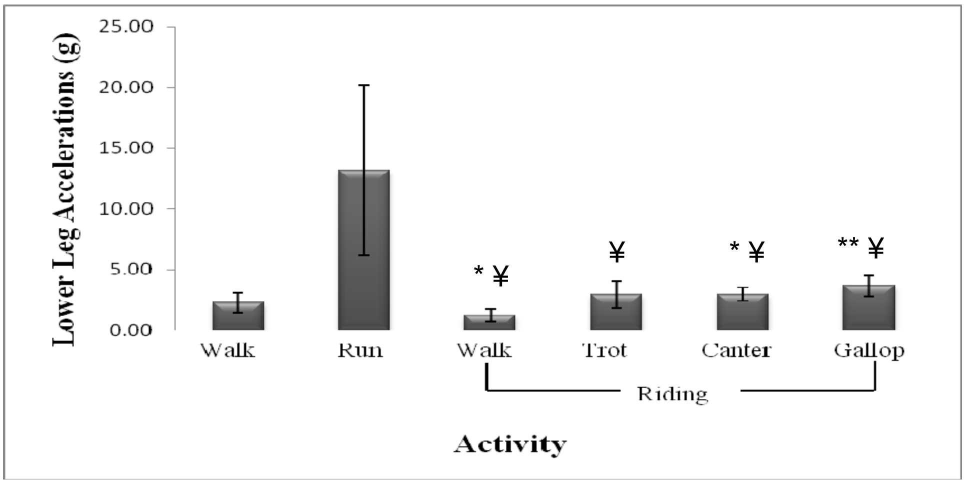

Figure 3: Activity dependent accelerations in the lower leg. The significant difference of walking and running to each of the riding activities is shown (*$p \leq 0.05$ for walking; **$p \leq 0.01$ for walking; ¥$p \leq 0.01$ for running).

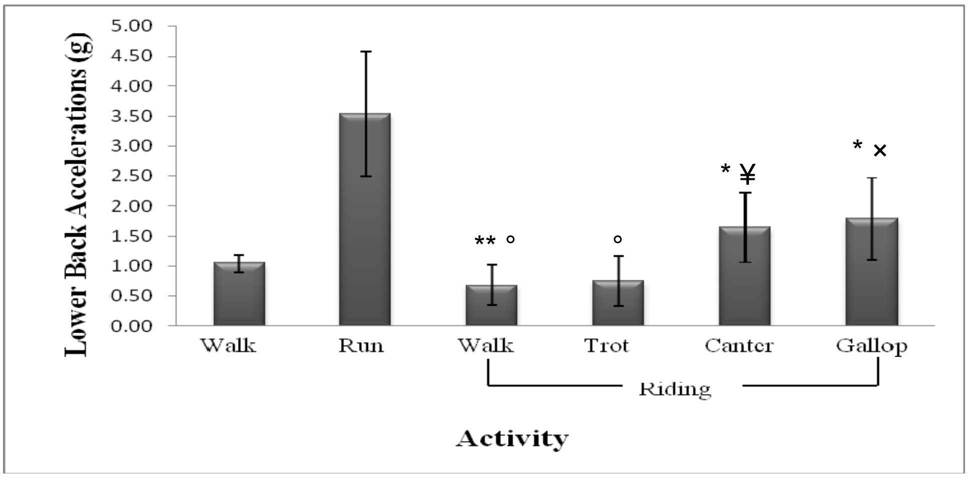

Figure 4: Activity dependent accelerations in the lower back. The significant difference of walking and running to each of the riding activities is shown (*$p \leq 0.05$ for walking; **$p \leq 0.01$ for walking; ×$p \leq 0.05$ for running; ¥$p \leq 0.01$ for running; °$p \leq 0.001$ for running).

DISCUSSION: Based on a thorough analysis of current literature, no other studies were found that investigated the lower limb accelerations in jockeys during riding; therefore no comparative data is currently available. Depending on the horse riding gait chosen, noticeable differences in lower limb accelerations were observed. The lower limb accelerations in this study were significantly lower to all other accelerations while the subject was walking on the horse. Trotting resulted in impact accelerations quite similar to those for an individual walking on the ground. The riding gait that resulted in the greatest impact accelerations of the lower leg and lower back was galloping, however, a horse would not be able to remain galloping for a long period of time, so for the majority of training, the gait of cantering would be used. Although these riding accelerations during cantering were still significantly lower than those produced when the individual was running, observation of the acceleration patterns suggest that the impacts in riding were produced at a much greater frequency than those of the individual walking or running. To optimise bone health, it has previously been suggested the exercise includes mechanical loading strains of a high rate and magnitude, distributed in an unusual manner (Bailey et al., 2008). In one study of cyclists it was reported that the non-weight bearing nature of the activity coupled with the reasonably fixed body position adopted provokes a repetitive muscular strain pattern of moderately low magnitude and regular or even distribution (Nichols et al., 2003). In the current study, although a greater frequency in impact accelerations was observed in cantering compared to walking and running, the cycling theory may also be applied to the sport of horse racing such that the jockey does not 'sit' on the horse during cantering and galloping, but rather grips the horse with knees, ankles, and thighs. The relatively low impact nature of the sport of horse racing in addition to the even distribution may mean that jockeys do not receive sufficient weight bearing activity needed to maintain and increase BMD. Alfredson et al. (1998) reported that no significant difference in BMD existed between a group of female horse riders and the non actives at any site measured, suggesting the impact forces during riding are not sufficient to create osteogenic strains on the skeleton. Furthermore, conflicting evidence regarding the extra exercise jockeys partake in leaves doubts as to whether sufficient impact loading is attained elsewhere (Labadarios et al., 1993; Leydon et al., 2002).

CONCLUSION: This study aimed to evaluate the impact forces placed on the lower limbs of the horse racing jockey during riding and compare this with data from traditional weight bearing activities, including walking and running. Results indicated that the chosen gait of the jockey determined the impact acceleration. Lower limb accelerations during walking on legs are similar to trotting on a horse, greater than walking on a horse, however significantly lower to cantering and galloping. Running resulted in much greater lower limb accelerations compared to all other activities. The relatively non-weight bearing nature of the sport of horse riding compared to running suggests that jockeys may not receive sufficient loading required to optimize and maintain adequate BMD levels. It appears that in addition to nutritional factors, the lack of sufficient loading in horse riding is a causal factor to the low BMD observed in jockeys. Further research is required to validate the findings of this study.

REFERENCES:

Alfredson, H., Hedberg, G., Bergstrom, E., Nordstrom, P. & Lorentzon, R. (1998). High Thigh Muscle Strength but Not Bone Mass in Young Horseback-Riding Females. *Calcified Tissue International*. 62, 497-501.

Bailey, C.A. & Brooke-Wavell, K. (2008). Exercise for optimising peak bone mass in women. *Proceedings of the Nutrition Society*. 67, 9-18.

Labadarios, D. (1993). Jockeys and their Weight Practices in South Africa. *South African Medical Research Council*.

Leydon, M.A. & Wall, C. (2002). New Zealand jockeys' dietary habits and their potential impact on health. *International Journal of Sport Nutrition and Exercise Metabolism*. 12, 220-237.

Nichols, J.F., Palmer, J.E. & Levy, S.S. (2003). Low bone mineral density in highly trained male master cyclists. *Osteoporosis International*. 14, 644-649.

McCrory, P., Turner, M., LeMasson, B., Bodere, C. & Allemandou, A. (2006). An analysis of injuries resulting from professional horse racing in France during 1991–2001: a comparison with injuries resulting from professional horse racing in Great Britain during 1992–2001. *British Journal of Sports Medicine*. 40, 614-618.

Reginster J.Y. & Burlet N. (2006). Osteoporosis: A Still Increasing Prevalence. *Bone*. 38: S4-S9.

Warrington, G.D., MacManus, C., Griffin, M.G., McGoldrick, P.A. & Lyons, D. (2006) Bone mineral density and body composition characteristics of top level jockeys. *Medicine and Science in Sports and Exercise*. 38 (5), 246.

Warrington, G., McGoldrick, A., Dolan, E., McEvoy, J., MacManus, C., Griffin, M. & Lyons, D., (2009) Chronic weight control impacts on physiological function and bone health in elite jockeys. *Journal of Sports Sciences* (In Press).

Welten, D.C., Kemper, H.C., Post, G.B., Van Mechelen, W., Twisk, J., Lips, P. & Teule, G.J. (1994). Weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. *Journal of Bone and Mineral Research*. 9 (7), 1089-1096.