DYNAMIC MEASUREMENT OF FORCE WITHIN THE SHOE DURING CONDITIONS OF PERCEIVED EXERTION

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INTRODUCTION

Athletics and recreation are becoming a very large component of modern day society. Now, more than ever, more people are becoming very active and involved in recreational pursuits that include aerobics and running/jogging. The resultant increase in activity has lead to a noted increase in injuries (Nigg, 1985; Mckenzie et al., 1985). James et al (cited in Cavanagh, 1990), in a study of 180 injured runners identified three categories of running injury problem areas. These areas being: a) training errors; b) anatomic factors (biomechanics); and c) shoes and surfaces. Two thirds of these injuries were accounted for by training errors (increased mileage or increased intensity). Training errors concerning sudden increases in mileage or intensity tend to subject the body to new or greater than expected physiological stressors. Voloshin and Wosk (1981), have investigated the relationship between heel strike shock wave transmission and joint degeneration in walking subjects. Taken one step further, the implications of damage to the muscle-skeletal system by running is noted by Cavanagh (1990). This combined with the Nigg et al. (1983) data that suggests a relationship between the hardness of the athletic (running) surface and the incidence of injury has serious implications for the recreational runner/athlete. Clarke et al. (1985) have highlighted the possible injurious force involved in tibial accelerations that are the result of the runner taking longer strides. Since most people retain a constant stride frequency, as velocity increases, the athlete tends to increase their stride length. The resultant increase in stride length increases impact forces at the joint. This combined with the increase of ground reaction forces with higher running speeds (Munro et al., 1987) identifies high impact forces as a major factor to be considered when investigating the causal nature of running injuries. Research into the type of shoe and ground reaction forces has been equivocal. Nigg and Bahlsen (1988) have stated that shoes with the hardest mid soles elicit the lowest maximal vertical forces. Conversely other research has indicated that shoe hardness is related to higher (vertical) loading rates. Listed above are a number of factors involved in the prediction of running injuries.

Further research is needed to discover the causative factors involved in etiology of sport medicine running injuries. An analysis of running shoes, in particular the vertical ground reaction forces, may account for dynamic patterns of gait. Running at different levels of perceived exertion may elicit clues as to the biomechanics patterns that may be injurious to runners. For example, the gait of a runner at the beginning of the run may be markedly different from the gait at the end of the run. Variables such as intensity and distance will greatly affect the athlete's form as they become more tired. Thus, the number of running injuries (2/3 of Clarke's population) as a result of improper training may be the function of bad form (gait mechanics). An analysis under different levels of exertion will identify patterns of pressure with the foot that may have implications for the construction and design of athletic footwear as well as training methods for runners.

This study was an attempt to understand the dynamic of in-shoe vertical ground reaction forces within the shoe under differing levels of perceived exertion. Research in the area of running shoe forces may lead to the development of a better product that will decrease the rate and type of running injuries.

METHODOLOGY

Thirteen recreational runners were recruited for participation in this study. Following successful solicitation an informed consent was signed.

The materials utilized in this study were: a) Tekscan Software; b) a 486 DOS based computer with mouse support; c) computer cuff data links; e) one calibrated Pre-Cor treadmill; f) a standardized walkway; g) a Borg Perceived exertion (RPE) chart; and h) a pair of 496 New Balance running (athletic) shoes.

The measurement technique employed in this study used an in-shoe force monitoring system called Fscan. The Fscan system utilizes a foot sensor that retains 960 individual sensors that retain capacitive transducer technology to gather pressure/force measurements. These foot sensors are trimmable to the individual needs or sizing of each subject. All subjects were fitted and ran in the same brand of athletic shoe.

This study involved the measurement of gait under a variety of conditions. These conditions included: a) walking at normal gait conditions; b) jogging at fifty percent along the same walkway; c) walking at three miles per hour on a treadmill; d) running at a light pace that elicited a perceived exertion value of between 6 and 11 on the RPE scale; e) running at a self-reported moderate pace that elicited a value of between 12 and 16 on the RPE scale; and f) running at a hard pace that elicited a self-reported value of between 17 and 20 on the RPE scale. The RPE scale is color coded for ease of use and explanation (blue for light values 6 to 11; green for moderate values 12 to 16; and red for hard values 17 to 20).

The subject, after an acclimatization period on the treadmill, was weighed and fitted with a pair of New Balance running (athletic) shoes. The subject was first asked to walk down a standardized walkway at normal gait conditions. Then the subject was asked to run down the hallway at fifty percent of their maximal running gait. The subject was then placed on a treadmill and the velocity was set at 3.0 miles/hour. The subject was then stopped and asked training information as to what pace would be a comfortable training run. The subject was then given an explanation on the usage of the RPE scale. Based upon self-reported training data the subject ran at a moderate pace. The subject was asked to respond to the RPE chart at the beginning of every minute during the test. A measurement was taken when the subject reported a value that was in the middle of the light section of the RPE scale. Two measurements were taken at each stage. The subject's velocity was increased to their training pace for a medium distance race. This placement ensured a moderate rating of perceived exertion. The velocity was increased one half mile per hour every two minutes to ensure a that a high RPE value would be established.

The following research questions were asked:

1) Are pressures differentiated by condition of perceived exertion, i.e., does gait change when one becomes tired?

2) Would an increase in velocity be reflected in differential patterns of pressures across the foot (heel, mid-, and forefoot)?

3) Are there bilateral differences?

4) Do treadmill walking and running pressure scores differ from hallway walking and

running pressure values?

RESULTS AND DISCUSSION

Under differing levels of perceived exertion there are changes in gait cycle mechanics and force. The heel region produced the least amount of change. The values in the heel ranged from 354.11 to 486.72 N across all conditions. The mid foot region exhibited a range from (walk) 219.78 to (hard run) 478.32 N. The values in the forefoot region of the foot differed the greatest ranging from 545.95 to 1020.93 N. The forefoot region of the foot demonstrated the largest percentage of increase across the running trials. The pressure scores of the forefoot across the three running trials were statistically independent of each other ($p \geq 0.05$). This distribution of pressure scores across all trials in the forefoot provides data for debate concerning the design of the forefoot region of athletic shoe insoles. Thus, across greater levels of perceived exertion a disproportionate amount of force is being exerted in the forefoot region of the foot. Such forces may be the cause of running injuries such as plantar fasciitis, metatarsal head pain, etc.

A paired t-test was used to identify bilateral differences between the same areas of the left and right foot (e.g. walking left heel with walking right heel). Although statistical differences were not evidenced, bilateral pressure scores were large in the moderate run (left forefoot 783.20 N, right forefoot 922.54 N) and the hard run (left forefoot 842.95 N, right forefoot 1022.25 N). The high amount of variation and small sample size were factors deemed salient to a low alpha value (statistically non-significant finding).

Treadmill walking produced vertical ground reaction forces that were the lowest of all trials and experimental conditions. The hallway and treadmill walking pressure scores were very similar. As well, the hall jog and the light RPE run force values were very close, indicating that the gait analysis machine displays a measure of internal consistency. The low vertical ground reaction force data found in the treadmill walk raises some interesting questions concerning rehabilitation protocols. Further research is needed to determine the relationship between in-shoe vertical ground reaction forces and shear. This research should perhaps focus upon over ground and treadmill running/ walking.

CONCLUSIONS

Based on the results of this study, the following conclusions can be made:

1) Stride frequency does not change between levels of moderate to hard perceived exertion.

2) Bilateral differences were found to be statistically non-significant. The moderate and hard running trials demonstrated the highest amount of variance between the left and right foot.

3) Treadmill walking produces the least vertical ground reaction forces across all situations.

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