

# PREDICTORS OF A RESPONSE TO WINDLASS MECHANISM ENHANCING RUNNING SHOES

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## INTRODUCTION

The windlass mechanism (Hicks, 1954) is that functional process in the foot in which upon heel lift, the first metatarsophalangeal joint dorsiflexes. This has the effect of 'winding' the plantar aponeurosis around the first metatarsal head, elevating the arch and inverting the rearfoot. A number of deficits have been identified in this process, such as a rigid first metatarsophalangeal joint (the windlass will not work), a high force needed to establish the windlass mechanism and a delay to the onset of the windlass mechanism. The forces needed to establish the windlass mechanism, by dorsiflexing the first metatarsophalangeal joint has been shown to be higher in those with plantar fasciitis (Payne, 2005). Foot orthoses have been shown to lower the force needed to establish the windlass mechanism (Payne, 2003). A number of foot orthoses and footwear design parameters have been shown to lower the force to establish the windlass mechanism (Kogler et al, 1996, 2001; Payne et al, 2005). Recently there has been increased attention given to the windlass mechanism by running shoe manufacturers. A number of running shoes are now available and are marketed as having the effect of potentially enhancing the windlass mechanism. The aim of this project was to determine the response of individuals to these shoes in enhancing the windlass mechanism and if the response could be predicted.

## METHODS

The running shoes that have the potential to influence the windlass mechanism were obtained from Nike (*Air Structure*), New Balance (*1050*) and ASICS (*Gel Empire*). Each company was asked to suggest a running shoe from their range that was similar but was not considered to have the windlass enhancing features of the other shoe. The shoes considered non-windlass enhancing were the Nike (*Air Pegasus*), New Balance (*765*) and ASICS (*Gel DS Trainer*). The New Balance has firmer midsole material under the hallux ('*stability platform*') that could potentially dorsiflex the hallux, initiating earlier windlass activity. The Nike has a softer midsole material under the medial column ('*WARP technology*') and the Asics as number of features that would have this effect ('*Space Trusstic*' system). A size 9.5 was obtained of each shoe (6 pairs) and participants were recruited who fitted this size shoe, were healthy and had no orthopaedic, surgical or neurological problems. A previously described device (Payne, 2005) was used to measure the static timing of windlass activation and the force to establish it. Participants stood on a platform that is hinged at the first metatarsophalangeal joint so the joint can be dorsiflexed. The force to dorsiflex the hallux at 8, 18 and 28 degrees was measured with a force gauge in Newton's (ie the force to establish the windlass mechanism). The angle at which the hallux needed to be dorsiflexed before the arch starts to raise was also measured (ie the dorsiflexion needed before the windlass activates). Only the left foot was measured. The Pedar™ in-shoe pressure measuring system was used to determine differences in foot function between the windlass and non-windlass enhancing shoes of each manufacturer. Participants walked at 4km/hr on a treadmill in the 6 different running shoes conditions, with the order being randomly assigned. Subjects spent 5 minutes acclimating to the treadmill before data collection and 2 minutes acclimating to each shoe condition before plantar pressure data was collected for 30 seconds. The plantar pressure data was analyzed by averaging the middle 15 steps of the left foot of the data collected. Masks were created over the heel, lateral forefoot, first metatarsal head and the hallux areas. In each mask the Novel software determined contact time (ms), mean maximum pressure (kPa), pressure time integral (kPa/s), force time integral (N/s) and the instant of peak force (as a % of stance phase). Repeated measures ANOVA was used to determine if there were any differences between the different running shoe conditions, with post-hoc t-tests used to determine where the difference were. Pearson's r was used to determine the correlation with the differences between the windlass and non-windlass running shoe of each shoe manufacturer and the force to establish the windlass mechanism and the timing of windlass activation.

## RESULTS

Twenty five subjects were recruited (15 male; 10 female; mean weight 72.7 ( $\pm$ 11.8) kg; mean age 21.5 ( $\pm$ 1.7) years). The mean degree of first metatarsophalangeal joint dorsiflexion before windlass tension was felt and observed by the examiner was 12.8 ( $\pm$ 5.3) degrees. The mean force at 8 degrees was 12.8 ( $\pm$ 5.2) N; at 18 degrees was 33.3 ( $\pm$ 21.8) N; and at 28 degrees it was 64.7 ( $\pm$ 29.1) N. With the plantar pressure parameters measured, repeated measure ANOVA showed there were systematic differences ( $p=0.017$ ) between the windlass and non-windlass shoes of each shoe manufacturer. There were also significant correlations found between subject specific differences between the windlass and non-windlass shoes of each company and the force to establish the windlass mechanism.

For the Nike shoes, there were systematic differences with lateral forefoot maximum mean pressures being lower [9.1 ( $\pm$ 1.8) vs 10.7 ( $\pm$ 2.1) kPa] and medial forefoot pressure being higher [13.4 ( $\pm$ 4.3) vs 12.1 ( $\pm$ 3.3) kPa] in the windlass shoe compared to the non-windlass shoe. For the subject specific differences between the windlass and non windlass shoe, the force to dorsiflex the hallux at 8 degrees was correlated to contact time under the medial forefoot ( $r = -0.67$ ;  $p = 0.017$ ) (the higher the force, the less contact time). For the New Balance shoes the systematic differences were a lower mean pressure under the heel [9.9 ( $\pm$ 1.6) vs 11.2 ( $\pm$ 1.6) kPa] and lateral forefoot [10.1 ( $\pm$ 1.8) vs 10.9 ( $\pm$ 1.2) kPa] in the windlass shoes. The instant of peak pressure under the heel was sooner with the windlass shoe [23.7 ( $\pm$ 4.8) vs 25.1 ( $\pm$ 3.6) % of stance]. For the subject specific differences between the windlass and non windlass shoe, the force to dorsiflex the hallux at 8 degrees and 18 degrees was correlated to the differences in the pressure/time integral in the heel between windlass and non-windlass ( $r = 0.72$ ;  $p = 0.02$  and  $r = 0.71$ ;  $p = 0.03$ ) (the lower the dorsiflexion forces, the lower the pressure time integral). For the ASICS shoes the systematic differences were medial forefoot mean pressures being higher [12.8 ( $\pm$ 2.4) vs 11.3 ( $\pm$ 2.1) kPa], heel pressure time integrals being lower [55.9 ( $\pm$ 6.8) vs 60.7 ( $\pm$ 7.1) kPa/s] and lateral forefoot pressure time integral being lower [58.9 ( $\pm$ 11.8) vs 69.2 ( $\pm$ 16.8) kPa/s] in the windlass shoe. For the subject specific differences between the shoes, there were correlations between all three angles and heel pressure time integrals (8 degrees:  $r = 0.67$   $p = 0.02$ ; 18 degrees:  $r = 0.68$   $p = 0.02$ ; 28 degrees  $r = 0.64$   $p = 0.03$ ); between the force at 8 degrees and the pressure time integral under the first metatarsal head ( $r = 0.66$   $p = 0.02$ ); and between hallux pressure time integral and the force at 8 degrees ( $r = 0.70$   $p = 0.01$ ) and 18 degrees ( $r = 0.69$   $p = 0.01$ ) (the higher the force, the higher the pressure time integrals).

## DISCUSSION & CONCLUSION

This study has shown that there are systematic differences for each respective shoe manufacturer between the windlass enhancing running shoes and the nearest equivalent non-windlass enhancing running shoe. It could be hypothetically assumed that if the windlass mechanism is functioning efficiently then there would be a more rapid movement of forces from the heel to the forefoot, greater forces under the medial column (due to first metatarsal plantarflexion as the windlass establishes) and a relatively lower forces under the lateral column. All the systematic changes seen between the windlass and non-windlass running shoes are consistent with this theoretical function. However, the changes were not seen in all parameters that could be expected to change. The force to dorsiflex the hallux (assumed to represent the force to establish the windlass mechanism) could theoretically be considered to be more efficient if that force was lowered. Based on this, it could then be assumed that if force to establish the windlass is high and a windlass enhancing shoe has the effect of lowering this force, then subject specific differences should be seen between the windlass and non-windlass shoe and this should be correlated to the force to dorsiflex the hallux. All the subject specific differences seen in this study are consistent with a theoretical more efficient function of the windlass in windlass enhancing shoes in those with higher forces to dorsiflex the hallux. However, changes were not seen in all the parameters that could be expected to change, as a result of what is assumed to be a more efficient windlass mechanism function. These results also need to be interpreted in the context of the limitation that the data was only collected while walking and a treadmill walking as opposed to over ground walking was used (to control for speed between conditions). It would also be expected that the non-windlass enhancing shoes would also have an effect of enhancing the effect of the windlass somewhat, limiting the potential for finding differences. The differences between the windlass and non-windlass shoes were statistically significant, but were not great in magnitude.

This study has shown that there are some systematic functional differences between windlass enhancing running shoes and the nearest non-windlass enhancing running shoe and some of the subject specific response to these shoes can be explained by the force needed to dorsiflex the hallux (establish the windlass mechanism). This information could be tentatively be used to suggest that those with a higher force to dorsiflex the hallux, at lower angles of dorsiflexion, appear to benefit most from the design features to enhance windlass mechanism function. Further work is needed to further elucidate and predict these responses to better prescribe running shoe for individuals.

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