ACUTE EFFECT OF TEXTURED INSOLES ON BIOMECHANICS OF MAXIMAL CYCLING

Louise Burnie[1,2,3], Paul Barratt[4], Keith Davids[2], Paul Worsfold[3,5], Jon Wheat[2]

Department of Sport, Exercise and Rehabilitation, Northumbria University, Newcastle upon Tyne, UK[1]
Sport and Physical Activity Research Centre, Sheffield Hallam University, Sheffield, UK[2]
Biomechanics, English Institute of Sport, Manchester, UK[3]
Team INEOS Grenadiers, Manchester, UK[4]
Sport and Exercise Sciences, University of Chester, Chester, UK[5]

The aim of the study was to investigate whether a within-session intervention of textured insoles worn in participants cycling shoes altered maximal cycling power output and biomechanics. Ten track sprint cyclists performed sprints on an isokinetic ergometer with and without textured insoles. Key biomechanical variables (crank kinetics, joint kinematics and kinetics) characterising sprint cycling were measured. There was a significant reduction in average crank power for the sprints performed with the textured insoles (P = 0.029) potentially associated with the reported discomfort when using the textured insoles. There were no changes in any other biomechanical measures suggesting a textured insoles intervention may have little impact on maximal cycling performance.

KEYWORDS: coordination, joint moments, maximal power, somatosensory feedback, sprint cycling.

INTRODUCTION: The goal of maximal cycling is to maximise the mechanical power output delivered to the crank (van Soest & Casius, 2000). To achieve this, muscle and joint actions need to be coordinated to facilitate energy transfer from the muscles through body segments to deliver maximum effective crank force (Raasch et al., 1997). Rapid feedback on the position of the joints and limbs is provided by the somatosensory, visual, and vestibular systems to assist successful execution of a movement, such as maximal cycling (Miranda et al., 2016).
Textured insoles worn within shoes have been used to enhance the somatosensory feedback to the feet via the cutaneous mechanoreceptors in the sole of the foot, due to the mechanical deformation of the skin and soft tissue (Orth et al., 2013; Wilkinson et al., 2018). Textured insoles are a cheap, easy to use intervention which can be used outside the laboratory during sporting activities (Qiu et al., 2013). Textured insoles therefore might be a method to enhance somatosensory feedback to improve performance of high-speed movements e.g., at high pedalling rates required in track sprint cycling (Orth et al., 2013). It has been suggested that elite athletes may receive greater benefit from textured insoles interventions to improve performance (Hasan et al., 2016).
There are two potential mechanisms proposed why using textured insoles within cycling shoes may increase maximal cycling power. First, during maximal cycling the ankle joint works in synergy with the hip joint to transfer power produced by the hip extensor muscles to the crank (Raasch et al., 1997). Textured insoles have been shown to improve ankle proprioception (Waddington & Adams, 2000) and alter activation of the muscles crossing the ankle joint (Nurse et al., 2005). Using texture in cycling shoes may help the body regulate the muscles crossing the ankle joint to strengthen the hip-ankle joint synergy. Second, activation of the bi-articular hamstring muscles are important in controlling the direction of the force applied to the pedal (van Ingen Schenau et al., 1992). Van Ingen Schenau et al. (1992) highlighted that the bi-articular leg muscles may be strongly influenced by the cutaneous mechanoreceptors in the sole of the foot. It is hypothesised that textured insoles will enhance feedback to these receptors which might enable cyclists to improve their control of the external force applied to the pedal to maximise external power output.
The aim of the study was to investigate whether an acute within-session intervention of textured insoles worn in participants cycling shoes altered maximal cycling power output and

biomechanics. We hypothesised that the use of textured insoles in cycling shoes would immediately alter maximal cycling biomechanics.

METHODS: Ten track sprint cyclists (4 males and 6 females, age: 24.6 ± 16.1 yr, body mass: 72.0 ± 8.4 kg, stature: 1.70 ± 0.06 m, flying 200 m personal best: 11.58 ± 0.76 s) gave informed consent to participate in this study which was approved by the university ethics committee.
An isokinetic ergometer was set up to replicate each participants track bicycle position. Riders undertook their typical warm-up on the ergometer for at least 10 minutes, followed by one 4 s familiarisation sprint at 135 rpm. Riders then conducted 3 x 4 s seated sprints at a pedalling rate of 135 rpm with their personal cycling shoe insoles (baseline condition), followed by 3 x 4s sprints with the textured insoles (Evalite Pyramid Lightweight EVA, 3mm (code: OG1549), Algeos, Liverpool, UK) which were cut to match the participants original insole size.
The isokinetic ergometer had been modified so that the flywheel was braked by a motor to control pedalling rate of the sprint (Burnie et al., 2020). Participants started their bouts at the target pedalling rate, rather than expending energy in accelerating the flywheel. The ergometer was fitted with force pedals and a crank encoder, sampling at 200 Hz (Model ICS4, Sensix, Poitiers, France). Normal and tangential pedal forces were resolved using the crank and pedal angle into the effective (propulsive) and ineffective (applied along the crank) crank forces.
Two-dimensional kinematics of the participants' left side were recorded using a high speed camera with infra-red ring lights at 100 Hz (Model: UI-522xRE-M, IDS, Obersulm, Germany) (Burnie et al., 2020). Reflective markers were placed on the pedal spindle, lateral malleolus, lateral femoral condyle, and greater trochanter. Kinematics and kinetics on the ergometer were recorded by CrankCam software (CSER, SHU, Sheffield, UK) which synchronised the camera and pedal force data and was used for data processing to carry out inverse dynamics analysis. All kinetic and kinematic data were filtered using a Butterworth fourth order (zero lag) low pass filter using a cut off frequency of 14 Hz. Instantaneous left crank power was calculated from the product of the left crank torque and the crank angular velocity. The average left crank power was calculated by averaging the instantaneous left crank power over a complete pedal revolution. Joint angles were calculated using the same convention as Burnie et al., (2020). Joint moments were calculated via inverse dynamics using pedal forces, limb kinematics, and body segment parameters (de Leva, 1996). Joint powers at the ankle, knee and hip were determined by taking the product of the net joint moment and joint angular velocity.
Data were analysed using a custom Matlab (R2017a, MathWorks, Cambridge, UK) script. Each sprint lasted for 4 s providing six complete crank revolutions which were resampled to 100 data points around each crank cycle. The joint angles, angular velocities, moments and powers were averaged over these revolutions to obtain ensemble mean values for each trial. Owing to technical problems for three participants, their average for the sprints at 135 rpm for the textured insoles condition was calculated from two instead of three sprints.
Differences between average left crank power over a complete revolution for the baseline and textured insoles were assessed using paired *t*-tests and effect sizes (ES) were calculated. Differences between time series data (instantaneous crank powers, crank forces, joint angles, angular velocities, moments and powers) for the baseline and textured insoles were assessed using statistical parametric mapping; paired *t*-tests were used for all variables except crank forces where Hotelling's paired T^2 test was used (Pataky, 2010). The level of statistical significance was set to $P < 0.05$ for all tests.

RESULTS: Average left crank power over a complete revolution for sprints at 135 rpm significantly decreased ($P = 0.029$, ES = -0.14 (trivial negative effect)) in the textured insoles condition (462.8 ± 90.2 W) from the baseline (475.3 ± 90.9 W). Three participants reported initial discomfort when wearing the textured insoles.
There were no significant differences between baseline and textured insoles conditions for instantaneous crank power and forces, joint angles, angular velocities and moments for sprints at 135 rpm (Figure 1, Figure 2). Only the ankle joint power was significantly different ($P < 0.05$) between the baseline and textured insoles sprints for 119° to 130° of the crank cycle.

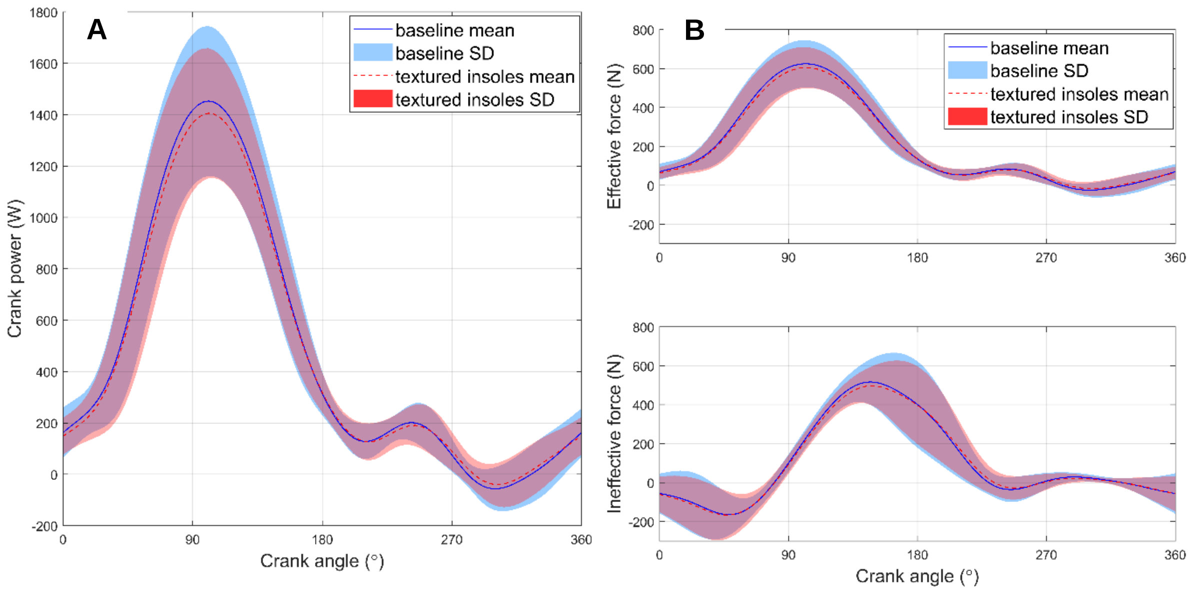

Figure 1: A) Crank power, B) Crank forces for sprints at 135 rpm: baseline and textured insoles conditions.

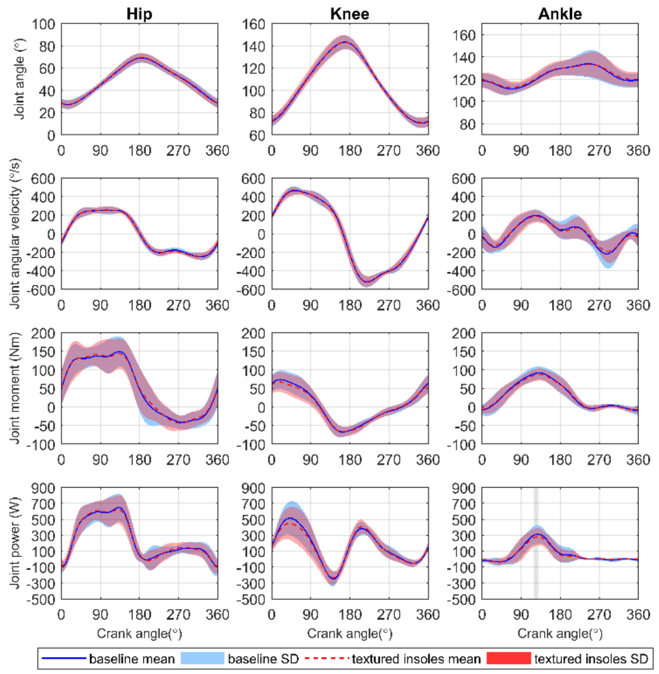

Figure 2: Joint angles, angular velocities, moments and powers for sprints at 135 rpm: baseline and textured insoles conditions. Areas of the graph shaded grey where the Statistical Parametric Mapping is significant.

DISCUSSION: There was a significant reduction in average crank power for the sprints performed by the cyclists using textured insoles in the acute condition. There were no changes in other biomechanical measures. The immediate reduction in crank power might be the consequence of initial discomfort when using the textured insoles in their cycling shoes, as several participants reported discomfort when sprinting using the textured insoles. Previous research has also reported that some participants experience mild discomfort when first using textured insoles, however this normally resolves after a few weeks of use (Kalron et al., 2015). This finding suggests the importance of good design of textured insoles and incorporating participant feedback to consider sensitivity. Intervention studies are required to assess the longer-term effect of textured insoles on maximal cycling power and biomechanics and whether the initial discomfort resolves.

Future research needs to consider whether the absence of any group changes in biomechanics might be because of individual responses to the textured insoles caused by the participants being in different functional groups (Nigg, 2010). Some participants could have responded to the addition of texture, whereas others did not (non-responders) due to how they performed the maximal cycling task. Also, the sensitivity of the participants cutaneous mechanoreceptors to pressure may influence their response to the stimulus of the textured insoles (Nigg et al., 1999). The participants in this study were well-trained cyclists, whereas in other studies (e.g., Hasan et al., 2016) participants were teenage footballers, performing a kicking task. There are differences in the characteristics of the movements – football kicking is self-paced interceptive action compared to cycling at maximal speed. The task constraints between the two movements differ greatly – in football kicking accuracy is important whereas in sprint cycling maximal power output is most important, which might be the cause in the different findings for our study compared to Hasan et al. (2016).

CONCLUSION: Textured insoles were found to cause an immediate reduction in maximal cycling power with no changes in biomechanics, suggesting that they may not be of benefit for use to improve maximal cycling coordination and consequently power output. Although future research needs to assess the long-term effects of using textured insoles during cycling.

REFERENCES

Burnie, L., Barratt, P., Davids, K., Worsfold, P., & Wheat, J. (2020). Biomechanical measures of short-term maximal cycling on an ergometer: A test-retest study. *Sports Biomechanics*, 1-19. https://doi.org/10.1080/14763141.2020.1773916

de Leva, P. (1996). Adjustments to zatsiorsky-seluyanov's segment inertia parameters. *Journal of Biomechanics*, *29*(9), 1223-1230.

Hasan, H., Davids, K., Chow, J. Y., & Kerr, G. (2016). Compression and texture in socks enhance football kicking performance. *Human Movement Science*, *48*, 102-111.

Kalron, A., Pasitselsky, D., Greenberg-Abrahami, M., & Achiron, A. (2015). Do textured insoles affect postural control and spatiotemporal parameters of gait and plantar sensation in people with multiple sclerosis? *PM & R*, *7*(1), 17-25. https://doi.org/10.1016/j.pmrj.2014.08.942

Miranda, D. L., Hsu, W.-H., Gravelle, D. C., Petersen, K., Ryzman, R., Niemi, J., & Lesniewski-Laas, N. (2016). Sensory enhancing insoles improve athletic performance during a hexagonal agility task. *Journal of Biomechanics*, *49*(7), 1058-1063.

Nigg, B. M. (2010). *Biomechanics of Sport Shoes*. University of Calgary.

Nigg, B. M., Nurse, M. A., & Stefanyshyn, D. J. (1999). Shoe inserts and orthotics for sport and physical activities. *Medicine and science in sports and exercise*, *31*, S421-S428.

Nurse, M. A., Hulliger, M., Wakeling, J. M., Nigg, B. M., & Stefanyshyn, D. J. (2005). Changing the texture of footwear can alter gait patterns. *Journal of Electromyography and Kinesiology*, *15*(5), 496-506.

Orth, D., Davids, K., Wheat, J., Seifert, L., Liukkonen, J., Jaakkola, T., Ashford, D., & Kerr, G. (2013). The role of textured material in supporting perceptual-motor functions. *PloS one*, *8*(4), e60349.

Pataky, T. C. (2010). Generalized n-dimensional biomechanical field analysis using statistical parametric mapping. *Journal of Biomechanics*, *43*(10), 1976-1982. https://doi.org/10.1016/j.jbiomech.2010.03.008

Qiu, F., Cole, M. H., Davids, K. W., Hennig, E. M., Silburn, P. A., Netscher, H., & Kerr, G. K. (2013). Effects of textured insoles on balance in people with parkinson's disease. *PloS one*, *8*(12), e83309.

Raasch, C. C., Zajac, F. E., Ma, B., & Levine, W. S. (1997). Muscle coordination of maximum-speed pedaling. *Journal of Biomechanics*, *30*(6), 595-602. https://doi.org/10.1016/S0021-9290(96)00188-1

van Ingen Schenau, G. J., Boots, P. J. M., De Groot, G., Snackers, R. J., & van Woensel, W. W. L. M. (1992). The constrained control of force and position in multi-joint movements. *Neuroscience*, *46*(1), 197-207.

van Soest, A. J., & Casius, L. J. (2000). Which factors determine the optimal pedaling rate in sprint cycling? *Medicine and science in sports and exercise*, *32*(11), 1927-1934.

Waddington, G., & Adams, R. (2000). Textured insole effects on ankle movement discrimination while wearing athletic shoes. *Physical Therapy in Sport*, *1*(4), 119-128.

Wilkinson, M., Ewen, A., Caplan, N., O'Leary, D., Smith, N., Stoneham, R., & Saxby, L. (2018). Textured insoles reduce vertical loading rate and increase subjective plantar sensation in overground running. *European Journal of Sport Science*, *18*(4), 497–503.