Journal of
Functional Morphology and Kinesiology

MDPI

Editorial

The "*Journal of Functional Morphology and Kinesiology*" Journal Club Series: Highlights on Recent Papers in Joint Biomechanics of Running

Marta Anna Szychlinska [1,*], Sergio Castorina [2], Silvio Lorenzetti [3], Angelo Di Giunta [2], João Rocha Vaz [4,5] and Clark Dickin [6]

1 Department of Biomedical and Biotechnological Sciences, Human Anatomy and Histology Section, School of Medicine, University of Catania, 95123 Catania, Italy
2 Polyclinic G.B. Morgagni, Mediterranean Foundation, Orthopedics Traumatology and Rehabilitation Unit, 95123 Catania, Italy; sergio.castorina@unict.it (S.C.); adigiunta@yahoo.com (A.D.G.)
3 Department of Health Science and Technology, Institute for Biomechanics, ETH Zürich, 8093 Zurich, Switzerland; sl@ethz.ch
4 Laboratory of Motor Behaviour, CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, 1349-017 Lisboa, Portugal; jprvaz@gmail.com
5 Universidade Europeia, 1500-210 Lisboa, Portugal
6 School of Kinesiology, Ball State University, Muncie, IN 47306, USA; dcdickin@bsu.edu
* Correspondence: marta.sz@hotmail.it; Tel.: +39-095-378-2043; Fax: +39-095-378-2034

Received: 23 June 2016; Accepted: 24 June 2016; Published: 28 June 2016

Abstract: We are glad to introduce the second Journal Club. On the occasion of the recent Global Running Day, the first of June 2016, the second edition is focused on several relevant studies published recently in the field of Joint Biomechanics of Running, chosen by our Scientific Board members. We hope to stimulate your curiosity in this field and to share with you the passion for the sport seen also from the scientific point of view. The Editorial Board members wish you an inspiring lecture.

Keywords: joint; biomechanics; running; gait cycle; stance phase; swing phase

1. Introduction

The biomechanical component of running is very important when studying the aetiology of various musculoskeletal injuries or the performance principles. To introduce the concept of joint biomechanics, it is necessary to understand what it is meant with the so-called "gait cycle". This cycle begins when one foot makes contact with the ground and ends when the same foot makes contact with the ground again. The gait cycle is divided into two phases: the stance phase, in which the foot is in contact with the ground, and the swing phase, in which the foot is in not in contact with the ground [1]. The gait cycle is the basic unit of measurement in gait analysis [2]. In running, the swing phase occurs before 50% of the gait cycle is completed. There are no periods when both feet are in contact with the ground. Instead, both feet are airborne twice during the gait cycle, one at the beginning and one at the end of swing [1,3], referred to as double float. The phase which is actually taken into account during the study of various injuries and performance principles is the stance phase, corresponding to the moment in which the foot and leg bear the body weight. This phase can be divided into four different stages: (1) initial contact, which marks the beginning of the stance phase. In this stage, the feet do not touch the ground, the front foot is about to land on heel, midfoot, or forefoot, and the back foot is in the swing phase; (2) absorption or loading response, in which the front foot is performing the controlled landing, characterised by deceleration and braking. In this stage, the knee and the ankle of the fore foot flex and pronate to absorb impact forces, and the tendons and the connective tissue within the muscles store elastic energy to be used in the propulsion phase; (3) midstance, in which the fore foot is directly under the hips taking maximum loa, and the ankle and the knee are at maximum flexion angle; and (4) propulsion, where ankle, knee, and hip of the fore foot push the body up and forwards, using the elastic energy stored during the braking phase. This stage finishes when the toe of the fore foot leaves the ground (a phase commonly called "toe off"), and the feet are both in the swing phase again. At this point, the heel of the fore foot starts to lift towards the backside, and its height and the returning force of the knee depend on hip extension and speed. Once the knee has passed under the hips, the lower leg unfolds and prepares again for initial contact, marking the end of the swing phase [4].

2. Recent Papers Regarding the Joint Biomechanics while Running

2.1. Effects of Running with Rocker Shoes on Joint Biomechanics

Highlight by Marta Anna Szychlinska

Running has become one of the most popular sports nowadays. This sportive practice is associated with the risk of several injuries related to joint overuse. This might be due to the excessive load on the joints, to incorrect posture while running, or both. The load reduction while running can result in reduced tendon overuse injuries such as Achilles tendinopathy. It has been shown in the literature [5,6] that rocker shoes can produce alterations in ankle biomechanics, especially during the push-off phase of gait. Among these changes, a reduction in plantar flexion moment (PFM) and ankle power generation has been demonstrated. In a recent and interesting study by Sobhani et al. [7], the effect of wearing rocker shoes during different running strike types (a midfoot and a forefoot strike type) was investigated on the biomechanics of the ankle, knee, and hip joints. For this aim, 16 female endurance runners underwent three-dimensional gait analysis wearing rocker shoes and standard shoes. The inclusion criteria were an age between 18 and 55 years, regular long-distance training (running for at least 10 km/week for a minimum of 5 km per session), and no history of self-reported severe musculoskeletal injuries in the lower extremity that could affect running performance at the time of measurement. Work, power, internal moment, and angle of the ankle, knee, and hip joints in the sagittal plane during the stance phase of running were determined for the dominant limb using the Vicon Plug-in-Gait model. The strike pattern was identified by the data obtained from an in-shoe plantar pressure system. It was observed that running with rocker shoes reduces both positive and negative work as well as PFM at the ankle, which indicates less force produced by triceps surae muscles and consequently lower mechanical loads on the Achilles tendon. This effect is more prevalent for runners with a midfoot strike pattern. At the same time, it was shown that running with rocker shoes increases mechanical work at the knee joint, suggesting that the use of the rocker shoes might increase the risk of knee overuse injuries.

2.2. Effects of the Foot Rotation while Running on External Knee Adduction Moment and the Lateral-Medial Shear Force

Highlight by Sergio Castorina

The knee joint has been shown to be the most common site for a running related injury. The knee pathologies can increase the chances of developing a degenerative osteoarthritis (OA), especially in older adults. This high prevalence of knee OA could be due to improper loading of the knee over many years, leading to excessive cartilage wear. Two biomechanical measures that have been associated with knee OA development are the external knee adduction moment (KAM) and the lateral-medial shear force (LMF) positioned medially to the knee joint centre during gait. The external KAM directly affects the loading of the medial and lateral compartments of the knee, and the magnitude of this moment is able to predict the magnitude of cartilage loss. It has been shown that external KAM is higher while running than it is in walking; therefore, runners may be at greater risk for progression of OA. Shear forces have also been shown to be detrimental to cartilage health [8–10]. Therefore, decreasing the magnitude of the external KAM and shear forces on the knees while running could help runners slow cartilage loss and keep their knees healthy for a longer period of time. Foot rotation during gait has been shown to alter the LMF and KAM. These changes have recently been investigated in an interesting study by Valenzuela et al. [11] on running. For this purpose, 20 participants performed five running trials in three randomised conditions (normal foot position, external rotation, and internal rotation) at a running speed of 3.35 $m \cdot s^{-1}$ on a 20-m runway. Kinematic and kinetic data were gathered using a 9-camera motion capture system and a force plate, respectively. It was noticed that the external rotation of the foot while running reduced the loads on the medial compartment of the knee by decreasing the KAM and LMF, suggesting that it may help to slow the progression of the medial knee OA; internal rotation of the foot also reduced the medial loads, but it was observed that it is a more unnatural intervention as the experimental subjects' normal running gait was with their foot externally rotated. Moreover, external and internal rotation reduced the shear forces on the knee, which may be helpful in slowing down the degeneration of knee joint cartilage when compared to the normal foot position while running.

2.3. Effects of the Foot-Strike Pattern while Running on Joint Biomechanics

Highlight by Silvio Lorenzetti

Usually the foot-strike patterns while running are divided into forefoot, midfoot, and rear-foot strikers. There is an ongoing discussion in the literature about kinetic and kinematic differences due to the strike pattern and about the connection to injury. In a recent systematic review, Almeida et al. [12] included 16 studies. These authors reported significant differences between forefoot and rear-foot strikers for the foot and knee angle at the initial contact as well as in the range of motion in the knee flexion. Comparing midfoot to rear-foot strikers, these authors reported a larger ankle dorsi-flexion range of motion and a smaller knee flexion range of motion. Finally, during impact, the rear-foot strikers had higher vertical loading rates compared to the forefoot strikers. Additionally, during impact, Giandolini et al. [13] analysed the shock acceleration in downhill trail running of 23 experienced trail runners. They measured the 3D accelerations continuously during an 8.5-km run. It was shown that the foot strike pattern influences the axial and transverse shock acceleration differently. The authors discuss that the transverse shock acceleration should not be neglected in the assessment of impact severity. A recent comprehensive systematic review including more than 70 papers combined with expert opinions, Barton et al. [14] focused on clinical and biomechanical findings related to running retraining interventions such as changing the foot strike pattern. In general, there seems to be limited evidence to support running retraining in the treatment of exertional lower leg pain and patellofemoral pain. Due to the potential benefits, experts suggested strike pattern alteration, but also advised caution due to a substantial adaptation period especially towards a forefoot strike pattern. For knee injuries, it was suggested that a change from a rear-foot to a forefoot strike pattern be made and, for Achilles tendinopathy and calf pain, a change from a forefoot to a rear-foot strike pattern, respectively.

2.4. The Effects of Mild-to-Moderate Hip Osteoarthritis on Lower Extremity Gait Kinematics and Its Relationship with the Pain

Highlight by Angelo Di Giunta

Hip OA can be a leading cause of pain and long-term disability and is normally managed either with surgical or with non-surgical therapies depending on its severity. In the majority of individuals with mild-to-moderate hip OA, the non-surgical treatment is the first option, and a detailed description of the impairments and functional limitations within that population becomes of fundamental importance in order to find the best therapeutic treatment option [15,16]. For this purpose, in a recent and interesting study by Leigh et al. [17], the lower extremity gait kinematics in mild-to-moderate hip OA patients and the relationship between kinematics and pain in these patients were valuated. In this cross-sectional study, 22 individuals with mild-to-moderate radiographic hip OA

(Kellgren-Lawrence grade 2–3) and 22 healthy age and body mass index (BMI) matched control subjects were recruited. Kinematic treadmill walking data were collected using an 8-camera 3D motion capture system at a frequency of 200 Hz. A two-way repeated measures analysis of variance estimated mean differences in gait kinematics between groups. The pain was assessed for each subject using a 10-cm Visual Analogue Scale (VAS) with extremes anchored at 0 cm (no pain) and 10 cm (worst imaginable pain). Correlations between gait kinematics and pain were assessed using a Spearman correlation coefficient. It was demonstrated that gait kinematics were altered across all joints and planes in hip OA subjects when compared to control ones. These altered gait patterns occurred predominantly across the pelvis and hip joint and do not appear related to a pain-avoidance mechanism. The authors suggested that these findings might be of a great interest for the clinical non-surgical management of the mild-to-moderate hip OA.

2.5. Patellofemoral Joint and Achilles Tendon Loads During Overground and Treadmill Running

Highlight by João Rocha Vaz

Running as a repetitive behaviour is a potential mechanism to attain overuse injuries. Particularly, patellofemoral joint and Achilles tendon are musculoskeletal structures more prone to excessive load. With running becoming more popular every day, some people choose to run on a treadmill and others overground. Some studies have shown that the kinematics of treadmill and overground running are similar [18]. However, other studies have reported greater peak ankle eversion [19], which ultimately may alter the Achilles tendon loading. One would expect that treadmill running would increase the load in some tissues due to its lack of step-to-step variability. Yet Hong et al. [20] reported a lower magnitude of maximum plantar pressure and force at the plantar areas, suggesting treadmill running can be useful in the early stage of rehabilitation programs. However, this study did not address the loading over specific anatomical structures. A recent study by Willy et al. [21] further investigated the loading in patellofemoral joint and Achilles tendon during both treadmill and overground running. To this end, eighteen (9 males, 9 females) healthy runners ran at their self-selected speed in both conditions while kinematic and kinetic data were collected for 10 s with a 10-camera motion capture system and with an instrumented treadmill or a forceplate. Authors estimated peak loads, the rate of loading, and cumulative loading of the patellofemoral joint and Achilles tendon. Contrary to the authors' initial hypothesis, patellofemoral joint loading did not differ between treadmill and overground running. On the other hand, a greater loading of the Achilles tendon was observed in treadmill compared to overground running. This means that treadmill running may be detrimental to the Achilles tendon. Although participants were at an injury-free condition, care should be taken when choosing where to run during rehabilitation programs. Future research on this topic is needed to further understand the differences between treadmill and overground running from a clinical perspective.

2.6. Age and the Mechanics of Running

Highlight by Clark Dickin

Engaging in physical activity throughout our lifetime has numerous benefits to both physical and psychological well-being. Running, a basic activity, requiring minimal equipment, is performed by millions of people of all ages around the world. For individuals over the age of 45 years, injury locations expand beyond the common injury site of the knee and begin to impact other parts of the lower extremity at an increased rate. While it is possible to remain active as we age, the potential for both acute and chronic injuries increases. DeVita and colleagues [22] addressed this issue by analyzing the relationship between age and the mechanics of running in an attempt to better elucidate the causes of age-related running injuries. As expected, the study found an overall decrease in running speed along with a reduction in stride length but not step rate. When contrasted to the kinematics and kinetics of running, aging was associated with reduced ankle torques and powers (breaking and propulsive) along with vertical and horizontal ground reaction forces. Further, the study developed a regression equation to predict age-related changes in gait. While the findings of reduced ankle powers and torques is not new, the DeVita et al. [22] study assessed and established a projected yearly decline in gait performance that may prove instrumental to rehabilitation and training professionals working with an aging clientele. Specific attention to the force and power-producing capacity of the ankle musculature may help to retain gait patterns and potentially reduce the incidence of injury, although longitudinal studies would need to be conducted to establish this effect. Future studies should also assess gait changes at the neuromuscular level and assess the efficacy of training programs designed to help combat these changes.

Acknowledgments: The special thanks goes to the Editorial Board members who wanted to commit to this new initiative of the journal with much enthusiasm and interest.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

KAM	knee adduction moment
LMF	lateral-medial shear force
OA	osteoarthritis
PFM	plantar flexion moment

References

1. Ounpuu, S. The biomechanics of running: A kinematic and kinetic analysis. *Instr. Course Lect.* **1990**, *39*, 305–318. [PubMed]
2. Gage, J.R. An overview of normal walking. *Instr. Course Lect.* **1990**, *39*, 291–303. [PubMed]
3. Novacheck, T.F. Walking, running, and sprinting: A three-dimensional analysis of kinematics and kinetics. *Instr. Course Lect.* **1995**, *44*, 497–506. [PubMed]
4. Mann, R.A.; Hagy, J. Biomechanics of walking, running, and sprinting. *Am. J. Sports Med.* **1980**, *8*, 345–350. [CrossRef] [PubMed]
5. Boyer, K.A.; Andriacchi, T.P. Changes in running kinematics and kinetics in response to a rockered shoe intervention. *Clin. Biomech.* **2009**, *24*, 872–876. [CrossRef] [PubMed]
6. Sobhani, S.; Hijmans, J.; van den Heuvel, E.; Zwerver, J.; Dekker, R.; Postema, K. Biomechanics of slow running and walking with a rocker shoe. *Gait. Posture* **2013**, *38*, 998–1004. [CrossRef] [PubMed]
7. Sobhani, S.; van den Heuvel, E.R.; Dekker, R.; Postema, K.; Kluitenberg, B.; Bredeweg, S.W.; Hijmans, J.M. Biomechanics of running with rocker shoes. *J. Sci. Med. Sport* **2016**. [CrossRef] [PubMed]
8. Lynn, S.K.; Costigan, P.A. Effect of foot rotation on knee kinetics and hamstring activation in older adults with and without signs of knee osteoarthritis. *Clin. Biomech.* **2008**, *23*, 779–786. [CrossRef] [PubMed]
9. Lynn, S.K.; Kajaks, T.; Costigan, P.A. The effect of internal and external foot rotation on the adduction moment and lateral-medial shear force at the knee during gait. *J. Sci. Med. Sport* **2008**, *11*, 444–451. [CrossRef] [PubMed]
10. Astephen, J.L.; Deluzio, K.J. Changes in frontal plane dynamics and the loading response phase of the gait cycle are characteristic of severe knee osteoarthritis application of a multidimensional analysis technique. *Clin. Biomech.* **2005**, *20*, 209–217. [CrossRef] [PubMed]
11. Valenzuela, K.A.; Lynn, S.K.; Noffal, G.J.; Brown, L.E. Acute effects of foot rotation in healthy adults during running on knee moments and lateral-medial shear force. *J. Sports Sci. Med.* **2016**, *15*, 50–56. [PubMed]
12. Almeida, M.O.; Davis, I.S.; Lopez, A.D. Biomechanical differences of foot-strike patterns during running: A systematic review with meta-analyis. *J. Orthop. Sports Phys. Ther.* **2015**, *45/10*, 738–755. [CrossRef] [PubMed]
13. Giandolini, M.; Horvais, N.; Rossi, J.; Millet, G.Y.; Samozino, J.-B.M. Foot strike pattern differently affects the acial and transverse components of shock acceleration and attenuation in downhill trail running. *J. Biomech.* **2016**, in press.

14. Baron, C.J.; Bonanno, D.R.; Carr, J.; Malliaras, P.; Franklyn-Miller, A.; Menz, H.B. Running retraining to treat lower limb inuries: A mixed-methods study of current evidence synthesised with expert opinion. *Br. J. Sports Med.* **2016**, *50*, 513–526. [CrossRef] [PubMed]
15. Nelson, A.E.; Allen, K.D.; Golightly, Y.M.; Goode, A.P.; Jordan, J.M. A systematic review recommendations and guidelines for the management of osteoarthritis: The chronic osteoarthritis management initiative of the U.S. bone and joint initiative. *Semin. Arthritis Rheum.* **2014**, *43*, 701–712. [CrossRef] [PubMed]
16. Mills, K.; Hunt, M.A.; Ferber, R. Biomechanical deviations during level walking associated with knee osteoarthritis: A systematic review and meta-analysis. *Arthritis Care Res.* **2013**, *65*, 1643–1665. [CrossRef] [PubMed]
17. Leigh, R.J.; Osis, S.T.; Ferber, R. Kinematic gait patterns and their relationship to pain in mild-to-moderate hip osteoarthritis. *Clin. Biomech.* **2016**, *34*, 12–17. [CrossRef] [PubMed]
18. Fellin, R.E.; Manal, K.; Davis, I.S. Comparison of lower extremity kinematic curves during overground and treadmill running. *J. Appl. Biomech.* **2010**, *26*, 407–414. [PubMed]
19. Hong, Y.; Wang, L.; Li, J.X.; Zhou, J.H. Comparison of plantar loads during treadmill and overground running. *J. Sci. Med. Sport* **2012**, *15*, 554–560. [CrossRef] [PubMed]
20. Sinclair, J.; Richards, J.; Taylor, P.J.; Edmundson, C.J.; Brooks, D.; Hobbs, S.J. Three-dimensional kinematic comparison of treadmill and overground running. *Sports Biomech.* **2013**, *12*, 272–282. [CrossRef] [PubMed]
21. Willy, R.W.; Halsey, L.; Hayek, A.; Johnson, H.; Willson, J.D. Patellofemoral joint and achilles tendon loads during overground and treadmill running. *J. Orthop. Sports Phys. Ther.* **2016**, *12*, 272–282. [CrossRef] [PubMed]
22. DeVita, P.; Fellin, R.A.; Seay, J.F.; Ip, E.; Stavro, N.; Messier, S.P. The relationship between age and running biomechanics. *Med. Sci. Sports Exerc.* **2016**, *48*, 98–106. [CrossRef] [PubMed]