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# THE EFFECT OF COMPLIANT RUNNING ON KINETICS AND JOINT KINEMATICS

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This study examined the differences in joint kinematics and kinetics between normal and compliant running, to determine the potential injury prevention benefits and running technique of the latter. Twelve subjects were familiarized with compliant running and completed a full motion analysis while running at a pre-determined, self-selected pace. Distinct differences in both joint kinematics and kinetics were recorded. This was represented by an increase in knee and hip flexion of 52% and 19%, respectively, as well as a decrease in knee and ankle peak extensor/plantar flexor moments of 49% and 43%. Hip flexor moments increased by 54%

**KEY WORDS:** Groucho running, compliant running, motion analysis, force plate, joint kinematics, kinetics.

**INTROUCTION:** Globally, running is one of the most popular modes of physical activity (Voloshin, Mizrahi, Verbitsky, and Isakov, 1998). However, the issue of musculoskeletal injury is increasingly evident, with up to 70% of competitive and recreational runners suffering from overuse injuries in any one-year period (Hreljac, 2004). In light of the benefits of running, it is extremely important to limit barriers to its undertaking. It is well established that injury development is associated with high impact loads (Lafortune et al, 1996; McMahon, G. Valiant, Frederick, 1987). Previous work has shown that adopting a compliant running style can decrease the magnitude of impact accelerations experienced by the body (Ó Catháin and Moran, 2013). Compliant running involves a lower center of mass (COM) height and less COM vertical motion throughout gait. However, from a kinematics point of view it is unclear what technique is employed. Also, other measures, such as vertical ground reaction forces (vGRF) and joint moments, have been implicated as significant risk factors to injury development (Whittle, 1999; Folman, Wosk, Voloshin, and Liberty, 1986; Hreljac, 2004; Clement and Taunton, 1980; Cavanagh and Lafortune, 1980; Radin, Eyre, Kellman, & Schuller, 1980; Wosk & Voloshin, 1981 Haim et al., 2012; Shakoor & Block, 2006). However, it is unclear what effect compliant running may have on these particular measures.
This study therefore aims to compare normal to compliant running with regard to their kinematics, vGRF and joint moments.

**METHODS:** Twelve healthy, male subjects between the ages of 18-31 were recruited from a university population (height, 177cm ±6.5cm; weight, 78kg ±6.5kg). All subjects had been involved in running activities for 6 months, at least three times a week. Motion analysis was used to measure joint moments, vertical ground reaction forces, and joint kinematics. This involved five runs at a self-selected pace where one right leg footstrike was examined in each trial. Subjects were familiarized as according to Ó Catháin and Moran (2013). Subjects wore the same shoes for each trial. Running speed was measured using speed gates set over a five meter distance. Ground reaction force data was collected with an AMTI forceplate (USA). Kinetic and Kinematic information were captured using 12 ME (Vicon Oxford Metrics, UK) high speed cameras by tracking the position of retroflective markers attached to 21 specific anatomical sites on each participant's body. The 21 markers were placed on each subject in accordance with the Vicon lower body and torso Plug-in-Gait model (Vicon Oxford Metrics, UK). Joint moments, angles and ground reaction forces were calculated using Polygon software (Polygon, Vicon Oxford Metrics, UK) and anthropometric data. Anthropometric measurements included body mass (78kg ±6.5kg), height (177cm ±6.5cm), leg length (95.3cm, ±4.7), knee width (109mm, ±4.4), and ankle width (72.9mm, ±3.6).

**RESULTS:**

**Table 1 Key kinetic and kinematics: compliant versus normal running**

| Variables | Compliant | Normal | Signif difference | % Diff. |
|---|---|---|---|---|
| **Hip flexion: foot strike (degrees)** | 58 (±12.06) | 48 (±7.7) | (F= 22.4,P=.001) | 19% (C>N) |
| **Hip flexion: propulsion (degrees)** | 43 (±14.64) | 33 (±6.96) | (F=7.0, P=0.02) | 26% (C>N) |
| **Peak hip flexor moment (Nm/Kg)** | 1.58 (±.914) | .90 (±.47) | (F=5.4, P=.04) | 54% (C>N) |
| **Knee flexion : foot strike (degrees)** | 29 (±9.04) | 17 (±7.05) | (F=38.5, P<.001) | 52% (C>N) |
| **Knee flexion: propulsion (degrees)** | 58 (±7.30) | 48 (±5.67) | (F=28.6, P<.001) | 19% (C>N) |
| **Peak knee extensor moment (Nm/Kg)** | 12.92 (±5.12) | 21.22 (±8.93) | (F=6.64, P=.028) | 49% (C<N) |
| **Peak ankle plantar flexor moment (Nm/Kg)** | 25.3 (±4.18) | 39.06 ±(7.63) | (F=55.2, P<.001) | 43% (C<N) |
| **Ground reaction force (Passive peak) (N/Kg)** | 6.78 (±1.41) | 8.01 (±1.39) | (F=9.12, P=.01) | 17% (C<N) |

C = compliant; N = normal

Compliant running resulted in significantly larger hip flexion during both foot-strike (compliant > normal by 19%) and propulsion (compliant > normal by 26 %). The same trend in results was seen for knee flexion with compliant running presenting significantly greater values during foot-strike (compliant > normal by 52%) and propulsion (compliant > normal by 19%). Normal running presented significantly greater extensor/plantar flexor moments at both the ankle (normal > compliant by 43%) and knee (normal > compliant by 49%). However, hip flexor moments were significantly smaller (compliant > normal by 54%). At a whole body level, normal running presented significantly higher vGRFs (normal > compliant by 17%).

**DISCUSSION:** Compliant running has been previously described as a style that advocates increased knee flexion and lower hip height at foot strike, and has been shown to reduce the magnitude of impact accelerations during running (Ó Catháin and Moran, 2013). It therefore has clear benefits in terms of reducing the potential for injury development. However, it was unclear to what extent joint kinematics are altered; this may be particularly relevant in relation to instruction in an applied setting (athletic therapists, physiotherapist, biomechanists etc). Results show that kinematics were significantly altered, with knee flexion increasing by 52% and 19% at foot strike and during the propulsion phase, respectively. It is also clear that compliant running entails a larger degree of hip flexion than normal running with significant differences of 19% and 26% at foot-strike and propulsion phases respectively (compliant > normal).

Joint moments measure the turning forces within a joint, and closely relate to the external moments generated around a joint by the associated ground reaction force (Matjacic, 2009). Stefanyshyn (1999) showed that increased knee moments resulted in increased stress within the patella-femoral joint leading to pain and the possible development of patella-femoral syndrome. Similarly it was found that an increase in moments experienced by the knee exaggerates pain associated with medial knee Osteoarthritis; in fact magnitude of knee moments is regarded a measure of severity for knee osteoarthritis (Haim et al., 2012; Shakoor & Block, 2006). Results show that moments at the knee are significantly less for compliant running (49%), thus possibly reducing the likelihood of injury. A similar decrease in ankle moments (43%) in compliant running further underlines its increased protective capacity.
An increase in moments at the hip of 54% in compliant running may be explained by the increased muscle action surrounding the hip, required to maintain the compliant posture. It should however be noted that this is a result of increased flexor moments, which have not been specifically implicated to our knowledge in the development of injury. However, the potential for increased strain on muscles involved in hip flexion supports the notion that a gradual and safe familiarization protocol should be established to allow appropriate adaptation.
Compliant running also significantly decreased vGRF by 17%. vGRF is a measure of the force applied to the body by the ground as a result of footstrike, and has thus been implicated in the development of numerous injuries (Whittle, 1999; Folman, Wosk, Voloshin, and Liberty, 1986; Hreljac, 2004; Clement and Taunton, 1980; Cavanagh and Lafortune, 1980; Radin, Eyre, Kellman, & Schuller, 1980; Wosk & Voloshin, 1981). More specifically, Ferber et al (2003) found that subjects with a previous history of tibial stress fractures showed a significant (36%) increase in vGRFs. Milner et al (2003) further suggests that very minor changes in GRFs, even if not statistically significant, may still be important as the cumulative effect of any increase may progress the development of overuse injuries such as stress fractures, when repeated over thousands of footstrikes. Therefore, the observed decrease in vGRF in compliant running (17%) may decrease the risk of stress fracture development for runners.

**CONCLUSION:** Compliant running was accomplished with greater hip and knee flexion. The subsequent vGRF and the knee and ankle joint extensor/plantar-flexor moments were significantly lower, indicating the potential for compliant running to reduce the likelihood of some running related injuries. An increase in flexor moments at the hip presents a case for appropriate familiarization to prevent hip flexor muscle strain.

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