Biomechanical analysis of the lumbar-pelvic-femoral complex during the one-sided tilt test: A pilot study in triathletes

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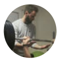

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Measurements were averaged in classes of ~0.2 m s^{-1}.

In each trial, the vertical component of the force exerted by the feet on the ground was measured using a force platform comprising eight contiguous plates, each plate 0.6 m long and 0.4 m wide that was mounted near the middle of a 40 m straight corridor (Willems et al. 1995). For running in sand, a wooden trough was mounted on the plates and filled to a depth of 7.5 cm with fine and dry sand.

From the vertical ground reaction force (F_v), the vertical acceleration (a_v), velocity (V_v) and displacement (S_v) of the COM were calculated as in Dewolf et al. (2016). The vertical stiffness (k) of the bouncing system was evaluated as the slope of the linear regression between the vertical acceleration and the vertical displacement of the COM during t_{ce} (Figure 1). A two-level ANOVA was performed to determine the effect of speed and ground surface on the running mechanics.

3. Results and discussion

The softness of the ground has a significant effect on the on-off ground symmetry: t_{ae} decreases when running on sand as compared to firm ground ($F = 25.8$; $p < 0.001$), whereas t_{ce} remains similar. When running on firm ground, the rebound is symmetric (i.e. $t_{ae}/t_{ce} \approx 1$) up to 3 m s^{-1}. These results are consistent with those reported in the literature (Dewolf et al. 2016).

When running on sand, t_{ae}/t_{ce} ~1 over the whole range of speeds (Figure 2A; $t = 0.45$; $p = 0.654$), since $\overline{a}_{v,ce}$ remains ≤ 1 g up to 4 m s^{-1} (Figure 2B). At a given speed, a lower $\overline{a}_{v,ce}$ is obtained by reducing the vertical stiffness k of the lower-limb ($F = 8.2$; $p = 0.005$) and the vertical displacement during t_{ce} (S_{ce}) as compared to firm ground (Figure 2C & D). Due to the lower $\overline{a}_{v,ce}$, V_v at take-off is reduced and the aerial phase is almost nil. Therefore, $t_{ae} < t_{ce}$ at slow speeds.

4. Conclusions

On firm ground, the bounce presents an *on-off ground symmetry* up to 3 m s^{-1}. At higher speeds, an *on-off ground asymmetry* appears to limit the internal power spent to reset the limbs each step. This asymmetry privileges the role of tendon relative to muscle in the storage-release of elastic energy.

When running on sand, extra positive work must be performed to overcome the dissipation of energy occurring in sand. To allow development of a lower force during the push -and in turn a smaller muscular power-with increasing speed, k and S_{ce} remain smaller than on firm ground. Consequently, bounce presents an *on-off ground symmetry* over a larger range of speed, privileging the role of muscle relative to tendon in the storage-release of elastic energy. Similar modifications of the *on-off ground symmetry* have already been observed when subject are requested to add positive work in the spring-mass system, for example when running uphill (Dewolf et al. 2016). Those observation strongly support the possible relationship between the on off ground symmetry and the contribution of tendon in the storage-release of elastic energy into the muscletendon unit (Cavagna 2009).

Acknowledgements

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KEYWORDS Biomechanics; running; bouncing mechanism; rebound asymmetry

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Biomechanical analysis of the lumbar-pelvic-femoral complex during the one-sided tilt test: a pilot study in triathletes

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1. Introduction

Training for triathlon requires athletes to spend multiple hours of training in swimming, cycling and

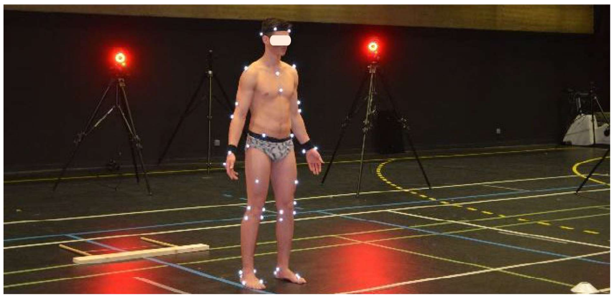

Figure 1. Experimental set up.

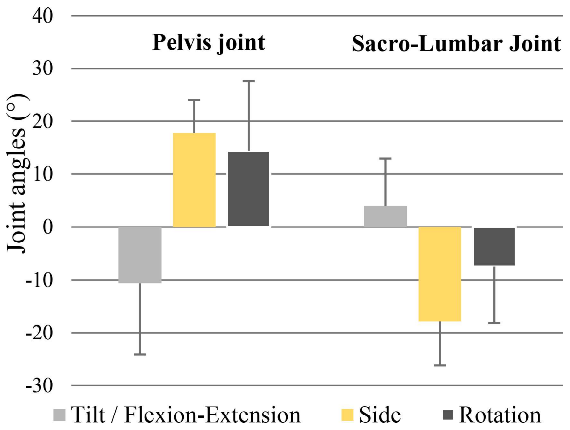

Figure 2. Sacro-lumbar and pelvis joint angles during the one-sided tilt test (mean of all trials).

Table 1. Mean of all degree of freedom joint angles of each class of participants.

Degree of freedom (°)	Class 1	Class 2	Class 3	Class 4
Pelvis				
Anterior (-) / Posterior (+) Tilt	8.2 ± 13.8	-4.9 ± 5.6	-8.1 ± 3.8	-30.0 ± 7.2
Ipsilateral (+)/ Contralateral (-) Side	7.9 ± 5.3	13.7 ±4.7	19.7 ± 3.8	22.9 ± 3.4
Controlateral (+) / Ipsilateral (-) Rotation	5.9 ± 17.1	5.2 ± 7.3	24.9 ± 8.7	25.3 ± 13.4
Sacro-lumbar				
Flexion (-) / Extension (+)	- 2.6 ± 3.7	-0.3 ± 4.8	-1.8 ± 5.1	18.1 ± 3.9
Ipsilateral (+)/ contralateral (-) Side	- 3.3 ± 6.5	-13.8 ± 5.9	-18.3 ± 5.3	-27.3 ± 4.2
Controlateral (+) / Ipsilateral (-) Rotation	- 8.6 ± 13.2	-7.2 ± 8.9	-15.7 ± 10.0	-5.4 ± 16.0
Hip Ipsilateral				
Flexion (-) / Extension (+)	6.4 ± 5.5	15.4 ± 6.1	18.7 ± 6.3	50.4 ± 5.7
Adduction (+) / Abduction (+)	-3.8 ± 9.4	-16.6 ± 6.5	-22.6 ± 5.3	-34.9 ± 8.0
External (-) / Internal (+) Rotation	-7.2 ± 14.6	-12.2 ± 14.8	-16.1 ± 8.4	-0.3 ± 9.1
Hip Contralateral				
Flexion (-) / Extension (+)	2.7 ± 9.1	-1.9 ± 6.6	6.8 ±6.8	27.8 ± 6.7
Adduction (+) / Abduction (+)	2.6 ± 7.4	12.5 ± 5.4	14.6 ± 4.4	25.7 ± 5.2
External (-) / Internal (+) Rotation	12.4 ± 19.0	8.1 ± 7.3	20.7 ± 7.7	19.6 ± 7.9
Knee Ipsilateral				
Flexion (-) / Extension (+)	-20.5 ± 6.3	-31.4 ± 4.2	-45.4 ± 5.7	-50.4 ± 2.8
Knee Contralateral				
Flexion (-) / Extension (+)	-5.1 ± 14.6	-6.9 ± 7.5	-1.7 ± 8.5	-0.6 ± 3.3

running. This training load increases the risk of injuries in lower back and the lower limb (Gosling et al. 2008). Despite an abundant literature, the evaluation of the risk of low back pain remains complex as it lacks evidence-based recommendations and reliable functional test. Several functional movement tools are suggested to evaluate this risk in assessing mobility and joint stability (Cook et al. 2014). However, it does not specifically investigate the range of motion of low back. The one-sided tilt test (also know as “hip drop test”) is an active voluntary movements used by osteopaths to analyse the one-side range of motions at the right and left side from a static position in individuals with nonspecific back pain (Chila 2010). The challenge is the clinical interpretation of this test though three-dimensional kinematic adaptations and musculoskeletal strategies of the movement performed on the test side and on the opposite side simultaneously on several regions (lumbar, pelvis, hip and knee). The aim of this pilot study was to use a musculoskeletal modelling approach to propose a functional screening approach of lumbar-pelvic-femoral complex range of motion during the one-sided tilt test.

2. Methods

2.1. Participants

Twenty-two well-trained and asymptomatic triathletes (age: 38.8 ± 12; years’ experience: 8.3 ± 9; training hours: 10.1 ± 3, male: 19; female: 3) were recruited for this study after completing a consent form and a questionnaire to exclude medical pathology. All components of the study were designed by the Research Department of the Institute of Osteopathy in collaboration with the M2S lab (#2018-277) according to the principles of the Declaration of Helsinki.

2.2. Protocol

The one-sided tilt test is used to examine the range of motions of the low back when tilting the pelvis to the right and to left side. To do this, the participant had to bend his knee allowing the pelvis to tilt to the same side. The test was explained to the participants and repeated several times before the recordings (Figure 1). After a static trial, participants were instructed to perform the right and left one-sided tilt test in an alternate sequence.

2.3. Musculoskeletal modelling

Three dimensional kinematics were obtained from a 24-camera motion analysis system (Vicon, Oxford, UK). Markers data served as an input of a full musculoskeletal model, developed by Raabe and Chaudhari (2016), to compute lumbar and lower limb joint angles from the recommended OpenSim calculation steps (Delp et al. 2007). The model was scaled to match the participants' anthropometry using anatomical landmarks (segment lengths) and joint angles were calculated with a global optimisation-based inverse kinematics procedure. All joint angles were estimated at the peak of the right knee flexion (right hand side) and for the left knee flexion (left hand side) for standardizing the procedure.

2.4. Statistical analysis

Latent class analysis was then used to identify different classes of movement combination. Significance level was not corrected for multiple testing and was set at $p < 0.05$.

3. Results and discussion

All participants performed the test on both side. Forty-four trials were analysed.

We observed an opposite kinematics between the pelvis (anterior tilt, ispsilateral side, controlateral rotation) and the sacro-lumbar joint (extension, contralateral side, ispsilateral rotation) (Figure 2).

Based on its results, four classes of possible movement combinations were identified (from Class 1 with the lowest range of motion to Class 4 with the highest range of motion) and characterised by an increase in knee flexion. In addition, highest ranges of motion (Class 4) occurred when the ipsilateral knee was more flexed and when the controlateral knee is close to full extension (Table 1).

Knee flexion was most limited with reduced range of motion of pelvis tilt, then rotation and finally list. These patterns were different between the left and right side in 31.8% of the studied population.

4. Conclusions

The main finding of this pilot study is that biomechanical analysis allowed to better understand musculoskeletal strategies during the one-sided tilt test. Polyarticular functional dynamics could help understand different strategies and kinematic adaptations linked to over or under mechanical load of specific joints. In addition, this approach permitted to identify athletes with limited range of motion on lumbar-pelvic-femoral complex. The use of a musculoskeletal approach allows the possibility in future studies of accessing data that are difficult to measure (muscle lengths and joint forces). A better understanding of how anatomical structures function and interact during functional movement is fundamental to prevent low back pain and to objectify the impact of osteopathic treatment for example.

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KEYWORDS Low back injury; kinematic analysis; functional test; functional screening; range of motion

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Dynamic analysis of the BMX start: interactions between riders and their bike

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1. Introduction

BMX Race is a sprint discipline with a race time between 30 to 40s and a track of approximately 400m. Because of the difficulties to overtake an opponent during the race, the start and the first straight line are crucial and have been shown to be directly correlated with rider's final position (Rylands and Roberts 2014). The start of the race includes 2.5-3 pedal strokes and race analysis has revealed that