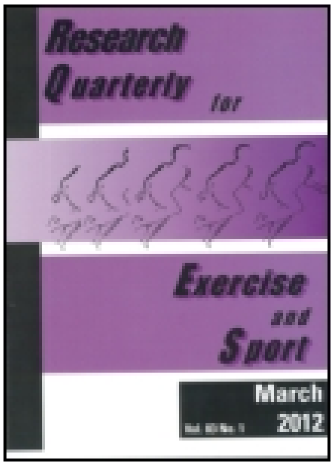

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The Effects of Psoas Major and Lumbar Lordosis on Hip Flexion and Sprint Performance

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The Effects of Psoas Major and Lumbar Lordosis on Hip Flexion and Sprint Performance

Karine Copaver, Claude Hertogh, and Olivier Hue

In this study, we analyzed the correlations between hip flexion power, sprint performance, lumbar lordosis (LL) and the cross-sectional area (CSA) of the psoas muscle (PM). Ten young adults performed two sprint tests and isokinetic tests to determine hip flexion power. Magnetic resonance imaging was used to determine LL and PM CSA. There were correlations between hip flexion power, sprint performance, and PM CSA, but LL showed no correlation with any parameter. The impact of hip flexion power and LL on sprint stride pattern efficiency was considered. Hip flexion might not have a simple role in the passive knee replacement of the stride pattern; instead, it may be an active parameter. Other investigations are needed to determine the influence of pelvic architecture on sprint performance.

Key words: efficient movement, running, track and field

Most sprint trainers recognize the importance of training the posterior muscles (Mero, Komi, & Gregor, 1992). However, the focus on this extension chain has had an indirect consequence: a decrease in the attention paid to another kinetic chain—hip flexion (Deane, Chow, Tillman, & Fournier, 2005). During the stride, the free leg returns in flexion under the pelvis. From its passage under the vertical line of the center of gravity, the thigh is raised while at the same time the leg segment oscillates forward (Chapman, 1982). Thus, it is important for athletes to have the means to raise and fix the thigh. In long-distance runners' stride, part of the forward return of the thigh depends on the hip flexors, which have been stretched during the impulse. In sprint running, the speed of segment mobilization is such that the return must be hyperactive (Mero et al. 1992). The flexion chain includes several muscles, especially the psoas major (PM), which is particularly interesting for its action on the spine and pelvis. To have an effective leg return, the concentric contraction of the PM, thus, seems to be indispensable in sprint racing (Vardaxis & Hoshizaki, 1989).

The role of the PM is controversial, notably concerning spine stabilization, and many authors have concluded that its function remains unclear (Richardson, Hodges, & Hides, 2004). Yoshio, Murakami, Sato, Sato, and Noriyasu (2002) concluded that its main function is to stabilize the spine by maintaining the femoral head in the acetabulum. The PM is often studied in the context of lumbar stress pathologies (Barker, Shamley, & Jackson, 2004), but it is also important because of its double action on the spine and pelvis. Moreover, this muscle allows the thigh to rise in walking and running stride patterns. In fact, if the femur is the fixed point, the PM bends the spine and pelvis forward, but if the fixed point is on the spine and pelvis, the PM is a hip flexor (Simon, Gouilly, & Peverelly, 2001). Authors have described the PM muscles as the main hip flexors in the stride pattern (Warwick & Williams, 1980). In the standing position, PM contraction leads to a pelvic posture favorable for sprint running, with the reverse of the anterior iliac spine (Dintiman, Ward, & Tellez, 1988; Mero et al. 1992).

Hoshikawa et al. (2006) studied the influence of the PM and the thigh's muscular characteristics on junior sprinters' performance. They analyzed the relationships

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between the cross-sectional area (CSA) of the quadriceps femoris (QF), the hamstrings and PM, and speed records for 100-m running. They found that the PM CSA relative to the quadriceps muscle is a determining factor in sprint performance. For junior sprinters of both genders, the authors showed that a more highly developed PM was a factor in achieving better 100-m race performance. Deane et al. (2005) showed that the increase in hip flexion strength after a period of hip flexion training improved sprint performance in active but not trained participants. Other authors, like Peltonen et al. (1998), showed that regular training increases muscular hypertrophy in the trunk region. They also concluded that muscle CSA was correlated with strength parameters. If we assume the following: (a) the PM is a hip flexor, (b) in the sprint stride, the leg return requires hip flexor action, and (c) muscle strength is strongly correlated with CSA, we can hypothesize that greater PM CSA is related to greater hip flexion power and that this influences sprint performance.

The spine is a column of bony joints—the vertebrae—and energy is lost if they are not "properly aligned." The lumbosacral hinge is the most likely to limit the transmission of ground reaction forces, because it is between the force restitution point (the pelvis, as it is aligned with the leg) and the body mass represented by the center of gravity (Hubiche & Pradet, 1993). Therefore, it is possible that the interaction between PM action and lumbar lordosis (LL) can influence hip flexion power. The literature is controversial concerning PM actions, notably concerning LL stabilization (Penning, 2000). Leg return is determined by the retroverted position of the pelvis, which corresponds to a backward tilt of the anterior superior spine and, thus, delordosis.

The purpose of the current study was to investigate whether PM CSA and LL significantly influence hip flexion power in sprint running. We hypothesized that: (a) hip flexion power and sprint performance would be highly correlated, (b) PM CSA would be correlated with hip flexion power and sprint performance, and (c) LL would be negatively correlated with hip flexion power and sprint performance.

Method

Participants

In accordance with French law, the study project was submitted to the university ethics committee, which gave its approval. The entire protocol was presented to the participants, and all gave informed consent before beginning the study. Ten Afro Caribbean natives volunteered to participate in this experiment. All participants were men (*M* age = 19 years, *SD* = 1; *M* body height = 177.2 cm, *SD* = 3.5; *M* weight = 71.5 kg, *SD* = 9.1). Their mean fat mass percentage was 11.8% (*SD* = 5.6). Fat mass percentage was obtained using an impedance balance. All participants regularly practiced sports, including soccer, tennis, track and field, and combat sports.

Psoas Muscle CSA

Magnetic resonance imaging was used to obtain PM CSA in the radiology department of a medical clinic (Centricity Radiology RA 600, Diagnostic 7.0; Spa 10; GE Healthcare Information Technologies, Milwaukee, WI). The measurements were taken while the participant was in a supine position with the legs straight. An experienced radiologist, who was not informed of the study aim, performed all measurements. Each examination lasted about 35 min.

The reference slice of the PM muscle was transversal, between lumbar (L) vertebrae 4 and 5. From a transverse slice of the PM muscle between L1 and sacral (S) vertebra 1, Barker et al. (2004) demonstrated that the most voluminous part of the muscle was at the L4/L5 level. Many authors use this slice as the reference for PM CSA. Longitudinal scans were used to identify the position of the lumbar vertebrae. Then a 10-mm thick transverse image (TR 250 ms, TE 20 ms, matrix 224 x 128, FOV 30 x 30 cm, 4 NEX) was scanned at mid-level between L4 and L5 (see Figure 1), as described by Peltonen et al. (1998).

Lumbar Lordosis

Traditional Cobb technique was used to measure LL. This measurement is made by drawing a line perpendicular to a line drawn across the superior endplate of the upper-end vertebra and the inferior endplate of the lower-end vertebra; the angle formed by the intersection of the two perpendicular lines is the Cobb angle, which is the measure of the magnitude of the lordotic curve. It is evaluated in degrees.

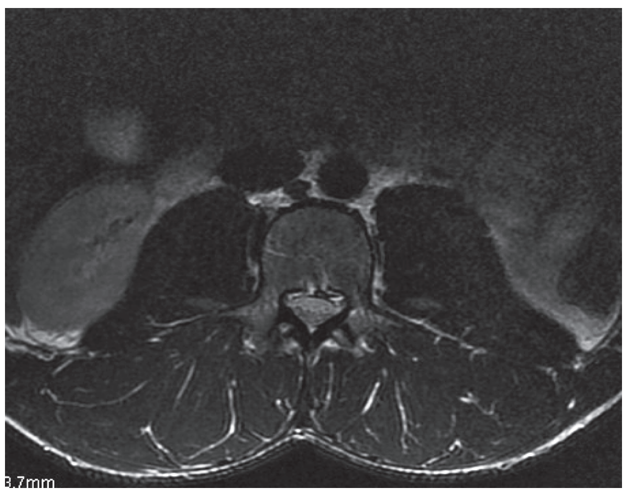


Figure 1. Magnetic resonance imagery slice of the psoas.

Hip Flexor Strength

The participants performed isokinetic tests (CONTREX MJ, Human Kinetics 1.6.1, Lyon, France) to determine hip flexion power (see Figure 2). They performed the tests in the physiotherapy department of a medical clinic. The physiotherapist in charge programmed and conducted the tests. To select the hip flexor action (notably PM), the physiotherapist determined an angular sector of 80° between the trunk and thigh, in line with the 70–90° recommended by other authors (Fauré et al., 2001). Participants performed all tests using the strength of their dominant leg, determined as the leg they used to jump after a run. Before beginning the experiment, a pretest was conducted.

After a 10-min warm-up on a cycloergometer, participants were placed on the machine in the supine position, with the dominant leg fastened by a strap at the lower part of the thigh. Angle flexion and extension were adjusted by a direct connection between the machine and the computer. This operation took about 3 or 4 min. Then the test began. At the end of the test, participants recovered on the cycloergometer at a free rhythm for 10 min. The entire test from warm-up to the end of recovery lasted more than 1 hr. Participants were asked to maintain total rest for 48 hr before testing and to drink water liberally (a minimum of 2 l per day for 3 days prior to testing).

Isokinetic Tests

Participants performed five isokinetic exercise tests. Before each test, three trials were held to familiarize them with the exercise modality, followed by 3 min of rest. At the end of the test, participants had 5 min of complete rest and then three familiarization trials before performing the next test. Once the tests began, all participants performed the same exercise using the same modalities. They performed all tests with their hands on the chest at two angular velocities: 120°/s and 180°/s, because these high velocities limit the implication of muscles other than the PM. Moreover, isokinetic devices are often used to evaluate hip flexor strength, but under certain conditions. Thus, the speed of movement execution is usually set between 130°/s and 180°/s. Beyond this speed, the isokinetic part of the movement is small (Herisson & Revel. 2000). The five modality tests were:

1. Five flexion-extensions of the thigh (120°/s)
2. Five flexion-extensions of the thigh (180°/s)
3. Five flexion-extensions of the thigh, with only concentric contractions of the hip flexors (120°/s)
4. Fifteen flexion-extensions of the thigh (120°/s)
5. Fifteen flexion-extensions of the thigh (180°/s).

In each modality, mean power (MP) and peak power (PP) were measured in the flexion phase.

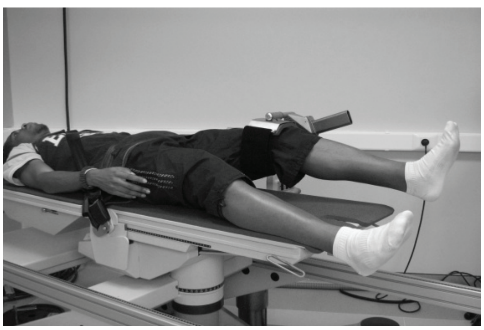
Sprint Tests

Participants performed sprint tests of 50-m and 120-m in one lane of a synthetic track. All wore their usual sports shoes. Before the test, they warmed up for about 20 min with a slow run, dynamic stretching, and some specific exercises. Performance time was assessed using photoelectric cells (Globus Tecnica e Sport, Codogne, Italy) placed on the start and finish lines. Each participant stood 1 m behind the line and, when ready, began to run. Participants performed each sprint test only once. After the 50-m sprint, they rested for 15 min; after that, they performed dynamic exercises for about 5 min and then ran the 120-m sprint. Simple regressions were performed to determine significant correlations between the parameters. Significant correlation was determined at $p < .05$.

Results

Correlations

50-m Sprint. Regression analysis revealed significant correlations between 50-m sprint performance and the power of hip flexion in six exercise modalities, particularly MP2 ($r^2 = .839$, $p < .001$), MP5 ($r^2 = .861$, $p < .001$) and PP5 ($r^2 = .823$, $p < .001$). Results are shown in Table 1.



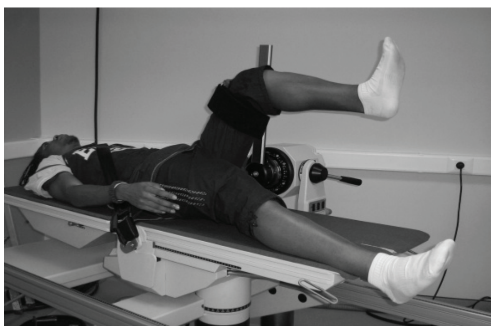


Figure 2. Positions during isokinetic exercises.

120-m Sprint. The 120-m sprint was significantly correlated with the mean hip flexion power, particularly concerning the modalities in which angular velocity was 180°/s for PP5 (r^2 = .888, $p < .001$) and MP5 (r^2 = .880, $p < .001$). Results are shown in Table 2.

PM CSA. There were significant correlations between the two sprint tests and the PM CSA for the mean power of hip flexion during performance of several modalities, particularly between 50-m and MP2 (r^2 = .532, $p < .01$) and MP4 (r^2 = .530, $p < .05$). These results are shown in Table 3. Figure 3 illustrates the relationships between PM CSA and MP2.

LL. There were no significant correlations between LL and any of the parameters tested. The minimum and maximum R^2 values concerned MP5 (R^2 = 1.128 E-4) and body height (R^2 = .182), respectively.

Table 1. Relations between the 50-m sprint and different modalities of isokinetic tests

	M	*SD*	R^2	*p*
120 m (s)	14.84	1.03	.858	.0001
MP1 (w)	97.38	32.76	.627	.006
MP2 (w)	113.36	38.26	.839	.0002
MP3 (w)	52.10	12.98	.043	.56
MP4 (w)	100.19	17.70	.606	.008
MP5 (w)	103.20	28.23	.861	.0001
PP1 (w)	237.62	56.64	.271	.12
PP2 (w)	332.22	65.67	.593	.009
PP3 (w)	219.01	46.19	.005	.83
PP4 (w)	255.86	33.81	.286	.11
PP5 (w)	338.50	20.50	.823	.0003

Note. M = mean; *SD* = standard deviation; MP = mean power; PP = peak power.

Table 2. Relations between the 120-m sprint and different modalities of isokinetic tests

	M	*SD*	R^2	*p*
50-m (s)	6.30	0.37	.858	.0001
MP1 (w)	97.38	32.76	.434	.03
MP2 (w)	113.36	38.26	.644	.005
MP3 (w)	52.10	12.98	.060	.49
MP4 (w)	100.19	17.70	.435	.03
MP5 (w)	103.20	28.23	.880	< .0001
PP1 (w)	237.62	56.64	.129	.30
PP2 (w)	332.22	65.67	.397	.05
PP3 (w)	219.01	46.19	.001	.94
PP4 (w)	255.86	33.81	.180	.22
PP5 (w)	338.50	20.50	.888	< .0001

Note. M = mean; *SD* = standard deviation; MP = mean power; PP = peak power.

Discussion

The main findings of this study were: (a) a strong correlation between hip flexion power and sprint performance, (b) significant correlations between PM CSA, hip flexion power, and sprint performance, and (c) no correlations between LL, hip flexion power, and sprint performance.

Hip Flexion Power and Sprint Performance

Performance in the 50-m and 120-m sprints was correlated with hip flexion power in all modalities except MP3. The strongest correlation concerned MP5, the test of 15 flexion-extensions in 180°/s (see Figure 4). It should be noted that the modalities from 1 to 5 increasingly resembled the conditions of short sprint races in both intensity and duration. Our finding, thus, confirmed the importance of hip flexion power in sprint performance (Deane et al., 2005). However, it was also interesting to note that this correlation was significant only for the power tested in some modalities, but not for all. This suggests the specificity of hip flexion power in having positive repercussions on sprint performance. The duration and intensity of Modality 5 was quite specific. Thus, the results of isokinetic tests conducted with only a low number of repetitions did not reflect the impact of the hip flexors during sprint racing. Therefore, the power supplied for Modalities 4 and 5 were more representative of 50-m sprint performance than Modalities 1 and 2 (which strongly correlated with performance in both sprint tests).

Hip Flexion Power and PM CSA

There were also significant correlations between PM CSA and hip flexion power, in agreement with the

Table 3. Relations between psoas cross-sectional area, sprint tests, and isokinetic tests

	M	*SD*	R^2	*p*
50-m (s)	6.30	0.37	.600	.008
120m (s)	14.84	1.03	.413	.045
MP1 (w)	97.38	32.76	.412	.04
MP2 (w)	113.36	38.26	.532	.01
MP3 (w)	52.10	12.98	.043	.56
MP4 (w)	100.19	17.70	.530	.01
MP5 (w)	103.20	28.23	.423	.04
PP1 (w)	237.62	56.64	.228	.16
PP2 (w)	332.22	65.67	.397	.051
PP3 (w)	219.01	46.19	.062	.48
PP4 (w)	255.86	33.81	.330	.08
PP5 (w)	338.50	20.50	.424	.04

Note. M = mean; *SD* = standard deviation; MP = mean power; PP = peak power.

strong correlation between muscle volume and produced strength (Maughan, Watson, & Weir, 1983). This correlation was stronger at 180°/s, which emphasizes the importance of its high speed action, particularly in sprint races. Andersson, Oddsson, Grundström, and Thorstensson (1995) showed that, although the iliac and

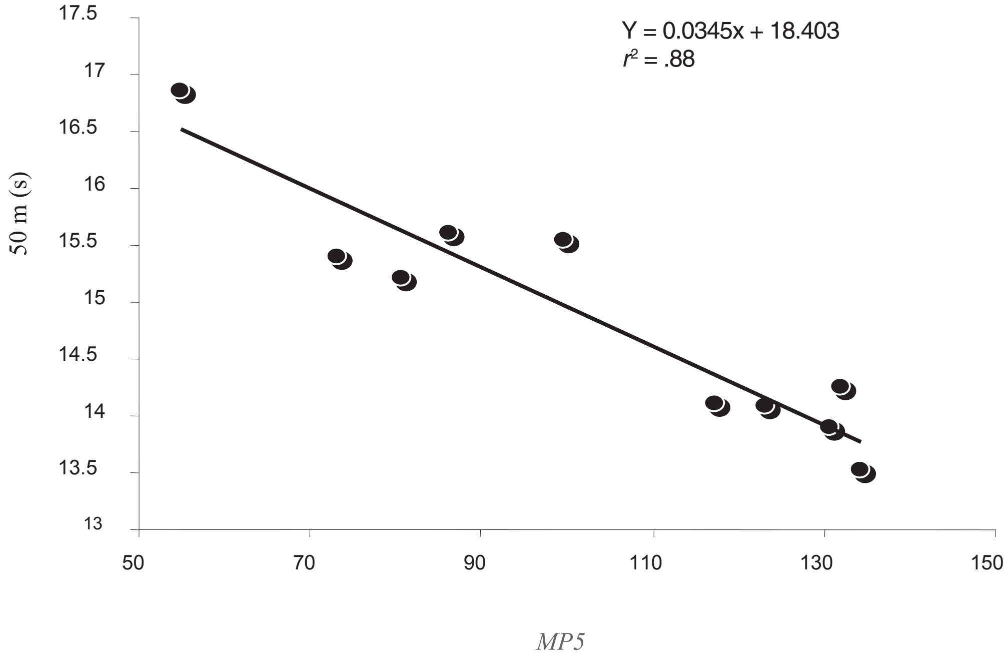


Figure 3. 50 m versus Mean Power 5.

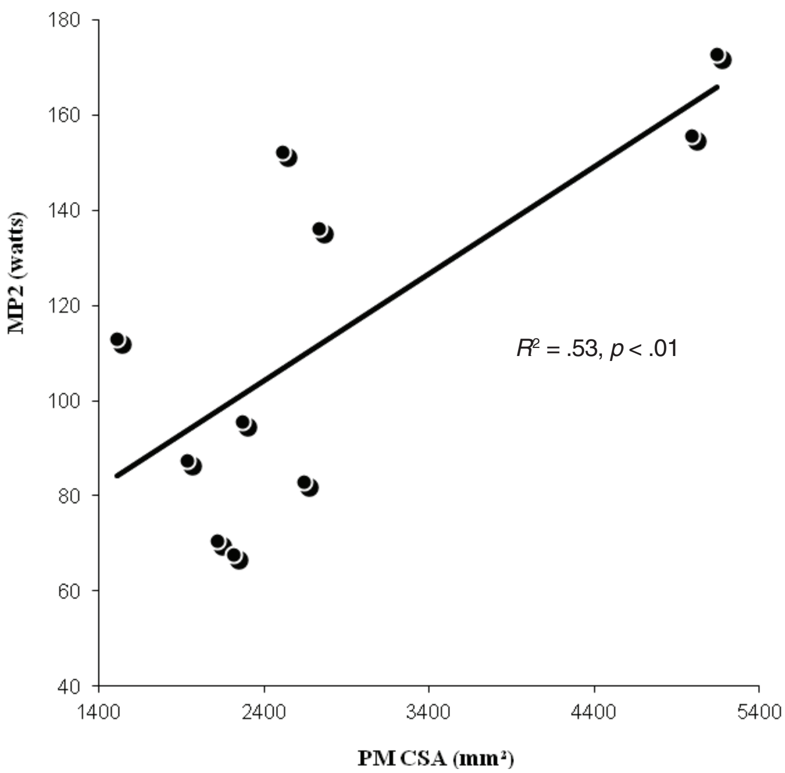


Figure 4. Psoas major cross-sectional area versus Mean Power 2.

PM muscles generally act together, in certain situations every muscle has specificities based on stability and movement requirements in the lumbar vertebrae, pelvis, and hips. One function of the PM is to maintain an optimal axis of rotation for the hip joint. In other words, the PM maintains the adaptation of the femoral head in the acetabulum. Thus, any situation that alters the position of the femoral head will affect hip function. Certain authors have demonstrated that PM activity increases when hip flexion is made against resistance (Gouriet, 1993). This information is interesting, specifically because the sprinter has to avoid the accumulation of rotational forces that would work against the quality of knee movement as the free leg swings forward.

The PM CSA was more strongly correlated with 50-m than 120-m performance. This suggests that, even in short sprint races, as race distance increases the sequence of high-intensity movements demands more coordination and more complex actions. This is especially so, as the PM is not the only hip flexor muscle. Despite the statistical significance, the correlations between PM CSA and the results of the two sprint tests suggest that other factors contribute to determining sprint performance. The PM alone does not affect stride pattern, but does so in concert with the other muscles of hip flexion movement—the trunk and thigh muscles, particularly the QF. Hoshikawa et al. (2006) showed that the ratio of PM CSA to quadriceps CSA was a factor in 100-m sprint performance. It would be interesting to test the influence of PM CSA on sprint performance in relation to a greater range of anatomical factors, such as other muscles and bone architecture. Pelvic width and depth, for example, might contribute information on hip flexion efficacy, not only regarding strength but also direction.

Hip Flexion Power and Sprint Race Technique

Hoshikawa et al. (2006) showed the active role of the PM in sprint performance, but they used indirect methods to assess how the PM CSA influenced top performances of elite juniors in the 100-m event. In the present study, we sought more precise and direct relationships between the PM CSA and several hip flexion parameters. On the other hand, within the framework of the Hoshikawa et al. study, they analyzed the PM in relation to the QF rather than in absolute value. It would be interesting to determine the anatomical parameters (e.g., abdominal muscles) that modify PM effects on hip flexion characteristics and sprint performance.

According to some authors (e.g., Wood, 1987), the main limit to short-distance running speed is the leg return (driving the leg forward following leg extension during the drive phase). As leg return depends on hamstring capacity, these authors suggested that eccentric training of this muscle group is indispensable for limiting injuries and improving performance. Our study confirmed the importance of PM actions for the efficacy of hip flexion power during the sprint stride. Although Wood's (1987) analysis is relevant, it may be incomplete. In fact, hip flexor action does more than point the knee forward. We suggest short-distance runners' leg cycle should be reconsidered, with greater attention on hip flexor action, particularly its role in creating velocity.

Exercise Modality 3

Exercise Modality 3 was particularly troublesome for all participants. In addition to a rapid flexion movement, they had to maintain the flexion against resistance and then realize another flexion movement, for a total of five repetitions. We assumed this modality would yield information on PM power. The results were inconclusive, however, and we think this exercise did not reflect "usual" or "natural" movement. Indeed, the most natural leg actions are walking, running, and jumping activities based on flexion-extension movements involving the agonist and antagonist muscles. Modality 3 did not reflect any of these ordinary movements and, thus, perturbed all participants.

LL and Hip Flexion Power

Magnetic resonance imagery (MRI) showed great interindividual variability in PM morphology. For some participants, the same slice showed the PM was much behind the vertebral body, whereas for others it was nearly at the same level as the vertebral body. This raises the question of the impact variability has on hip flexion power characteristics. Aaron and Gillot (1976) found that PM morphology was related to the lumbar curve. Given that the morphology of a muscle determines its surface and that LL influences muscle architecture, we wondered about the influence of LL on PM architecture and PM CSA and its repercussions on hip flexion power.

Pronounced LL is associated with a pelvic position with the anterior superior iliac spine tilted forward. In contrast, a small LL is associated with a pelvic tilt toward the back. In sprint running, this position is generally advantageous for efficient leg return. We hypothesized a negative correlation between LL and hip flexion power, although our results did not confirm this. One explanation is that for all participants, LL was within the normal range. Generally, the literature has shown mean LL values of about 40°, with extreme variations between 20 and 70° (Wambolt & Spencer, 1987). Thus, we can assume that LL must be far from the norm, or pathological, to influence hip flexion power. Another explanation is that participants' position during the MRI exam affected the sacral orientation. This might result in a difference between real and measured LL. However, there was no difference in the influence on lumbar curve when the individual was standing up or lying down on the back (Madsen, Jensen, Pope, Sorensen, & Bendix, 2008).

During sprint races, efficacy depends on the athlete's capacity to adopt and maintain a position with the pelvis (Dintiman et al., 1998). Therefore, it is possible that LL variations during the race increase or reduce the hip flexion amplitude and the quality of the leg return. During sprint races, the core muscles should reduce the anteroposterior pelvic variations that disturb the ground force transmission. In the present study, LL at rest did not influence hip flexion power. The variations in LL induced by sprint racing might be different. Moreover, the analysis of LL and PM CSA influences on the efficiency of hip flexion power while sprinting should take other anatomical factors into account. For example, the associations between the narrowness and depth of the pelvis and the psoas muscle insertions could influence hip flexion efficiency (its amplitude, direction, and strength) and sprint performance. In fact, it is possible that the more the distance between the acetabula increases, the more the PM acts as an external rotator. This might result in less well oriented hip flexion movement.

Conclusion

The aim of this study was to assess the influence of the psoas major cross-sectional area and lumbar lordosis on hip flexion power and sprint performance. We found no correlation between LL and hip flexion power, PM CSA, or sprint performance. However, it would be interesting to determine whether and in which conditions LL at rest would predict anteroposterior pelvic fluctuations during a race. In sprint training, pelvic fixation for optimal force transmission is indispensable. However, we found a positive correlation between PM CSA and hip flexion power, and a negative correlation between PM CSA and sprint running time. This indicates that individuals with naturally prominent PM have an advantage in performing rapid hip flexion movements during sprint running. These results have to be modulated, because the sprint stride in requires complex coordination with many muscle actions, including intermuscular compensations. Thus, one muscle alone cannot explain a physical result. Further investigations are necessary to determine the impact of the hip flexion muscles, as well as pelvic skeletal architecture, on hip flexion power in sprint running.

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Authors' Notes

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