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Effects of seat–thigh contact on kinematics performance in sit-to-stand and trunk flexion tasks

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ABSTRACT

It has been shown that thigh–seat contact-surface influences performance of isometric push-force with upper-limbs. The push-force performance is higher when subjects are seated with partial ischio-femoral / seat contact than when they are seated with full ischio-femoral contact. This was ascribed to greater pelvis and spine mobility induced by the short thigh–seat contact-surface. The present study tested the generalization of this hypothesis during movements involving body segment displacement, namely trunk flexion (TF) and sit-to-stand (STS) motor tasks. Both motor tasks were carried out in similar conditions to those implemented in the isometric push-force tasks, i.e. full ischio-femoral / seat contact (100-IFC) and short ischio-femoral contact (30-IFC, i.e. 30% of full ischio-femoral / seat contact).

Results showed that kinematic performances (maximal antero-posterior and vertical center of mass velocity and maximal backward displacement of center of pressure) in both motor tasks were higher in 30-IFC than in 100-IFC. In the sit-to-stand task, time of seat-off is shorter in 30-IFC. As the subject's initial global posture was comparable across the experimental conditions, it can be discarded as a source of performance change. It is discussed that it is the enhanced pelvis mobility induced by the sitting condition which is responsible for the increase of motor performance in both trunk flexion and sit-to-stand tasks. Our results highlight the role of joint mobility in motor performance.

1. Introduction

Archimedes (3c. BC) demonstrated that efficient force development requires an adequate support in human movement performance, this support is known as the postural basis. Ground reaction forces, i.e. the source of the movement, are hereby exerted through the postural basis. In other terms, the "quality" of the postural basis permits force generation and, consequently, movement. Enlarging the postural basis allows for higher performance speed, e.g. starting to walk with feet apart allows one to obtain a greater center of mass (CoM) progression velocity than with closed feet. Conversely, reducing the postural basis modifies the gait initiation program (Couillandre et al., 2002). Recent data shows that not only the postural basis but also "joint mobility" could participate in the kinetics and kinematics performance. The postural sway increase in standing low back pain patients has been attributed to reduced dynamic mobility capacity. This reduced mobility is in turn induced by an increase in tonic muscular activity (Hamaoui et al., 2004) rather than spine range motion which was found to be similar between low back pain patients and controls. Furthermore, in lower limb amputees, the origin of lower kinematics performance during gait was associated to suppression of joint mobility due to the prosthesis (Michel et al., 2004).

In a series of articles using pointing tasks and isometric push force by upper limbs while sitting in various configurations, performance is higher when a subject's seat–thigh contact is reduced. This allows better hip joint mobility (Lino et al., 1992; Lino and Bouisset, 1993; Le Bozec and Bouisset, 2004; Bouisset et al., 2006).

Are these results verifiable when heavier segments are mobilized?

The aim of the present paper was to test the generalization of this hypothesis during movements involving body segment displacement. The aim was to examine the effect of seat–thigh surface contact during motor tasks, more precisely the speed of sit-to-stand (STS). In line with previous results, a higher speed of STS was expected when subject was initially seated on a smaller seat–thigh area compared to a full seat–thigh area. However, as STS movement is composed of trunk flexion and body elevation, the expected speed increase may originate from the primo trunk flexion. To determine which factor is at the origin of speed increase, the effect of seat–thigh surface contact on trunk flexion speed was examined.

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2. Materials and method

Seventeen healthy young men without any known neurological or musculoskeletal disorders took part in this study. Their mean age, mean body mass and mean height were 28 ± 5 y.o, 76.5 ± 9.2 kg and 1.77 ± 0.09 m respectively. Subjects gave their informed consent. The experiments were conducted in accordance with the standards set by the declaration of Helsinki.

Two motor tasks were examined, trunk flexion (TF) and STS. Subjects performed the tasks from a sitting posture.

The seat of the stool was a square, solid wooden piece. The three rigid metal legs of the stool were fixed on a force platform (Bertec, 1.20 m x 0.60 m). Each stool foot was equipped with a vertical force sensor to record the time of seat-off (s-off). The stool seat was sufficiently large enough (0.55 m/sided) to allow full ischio-femoral/ seat surface contact (100-IFC). The stool's height was adjusted so that subjects' thighs were horizontal and legs vertical. The force platform delivered three forces (Fx, Fy, Fz) and three moments (Mx, My, Mz). Following a classical procedure, we obtained the three orthogonal center of mass accelerations as well as the planar coordinates of the center of pressure (Cop): $Xp = -My/Rz$; $Yp = Mx/Rz$. In the present study we were interested only in the kinematics parameters along the sagittal plane, i.e. the peaks of vertical and antero-posterior (A/P) CoM acceleration (Az, Ax), the peaks of vertical and A/P velocity (Vz, Vx), the maximum backward displacement of center of pressure (Xp) and the seat-off time.

Two experimental conditions were examined: a full ischio-femoral/ seat contact (100-IFC) and one third ischio-femoral/ seat contact, roughly 30% (30-IFC). In each condition, subjects performed 10 trials at maximal speed. The order of experimental conditions was randomly assigned to each subject. Breaks were set to one minute between experimental conditions. Their posture was standardized before each trial, with the shank and the trunk vertical, the thighs horizontal.The subjects were asked to keep their upper limbs near their body but were not constrained, to avoid oscillations both during and at the end of the movement in both seated conditions (Fig. 1).

Means were compared using a one way repeated measure analysis of variance (100-IFC versus 30-IFC), with the level of statistical significance fixed at $p < 0.05$.

Specific questions were addressed via two tests.

Test 1.

In this test it was investigated whether the subject's posture had changed between the two sitting conditions (100-IFC and 30-IFC). For that, we analyzed the mean CoP position, which is representative of subjects' posture, and CoP stabilogram, which represents subjects' postural oscillation, i.e. postural stability. Seven subjects took part in this session. They were asked to remain motionless for 1 min. The results showed that the CoP position, with respect to the heels and postural stability, was similar between the two sitting conditions. The means of maximum backward displacement of the CoP is the same for 100-IFC and 30-IFC (0.006 ± 0.002 m). Thus, the sitting condition did not affect subjects' initial posture.

Test 2.

Unlike in standing posture, where the postural basis and the polygon of support are confused by the feet perimeter, these two dimensions are distinct for the sitting posture. In sitting posture, the polygon of support, which includes the feet and the seat-foot support, is larger than the subject's postural basis, which is defined as the perimeter of contact between subject's body and ground support. Moreover, relative to 100-IFC, in 30-IFC condition where subjects sat at the front seat edge by advancing the buttocks and legs, the polygon of support, defined as the perimeter of the feet and rear seat legs, was enlarged. The polygon of support was thus larger in 30-IFC than 100-IFC (see Fig. 1). This test was set up to discard the influence of broad polygon of support linked with the different extent of sitting in the increase of the kinematics performance (cf. results). For this study, two different stools were used. One consisted of a rigid three footed metal stool fixed on a force platform (Bertec, $1.20\,m \times 0.60\,m$) (the one used in our test session) and the other a rigid four footed stool (20 cm large). In other terms, the main difference between the two seats was the antero-posterior dimension. Using both seats, seven subjects sat on their ischions (30-IFC in three footed stools) and performed 10 trials of STS. Subjects were instructed to perform this task as fast as possible. Results showed that the kinematics were the same across conditions (similar peak of antero-posterior and of vertical CoM velocity). The peak antero-posterior CoM velocity were 0.60 m/s and 0.62 m/s for four footed stools and three footed stools respectively ($F(1.6)=2.43$, $p > .05$). The peak vertical CoM velocity were 1.03 m/s and 1.00 m/s for four footed stools and three footed stools respectively ($F(1.6)=2.46$, $p > .05$).

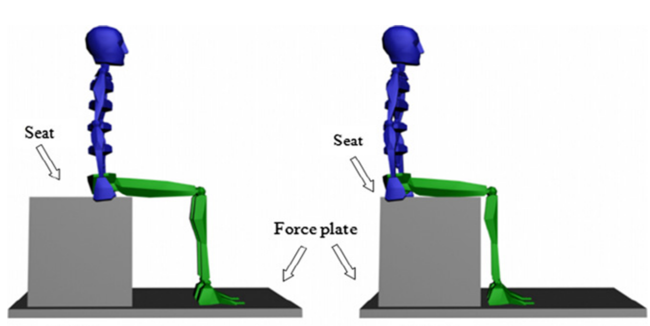

Fig. 1. Seat condition.

3. Results

3.1. Trunk flexion (TF)

Fig. 2 shows individual biomechanical traces of trunk flexion movement carried out in the experimental condition of 100-IFC.

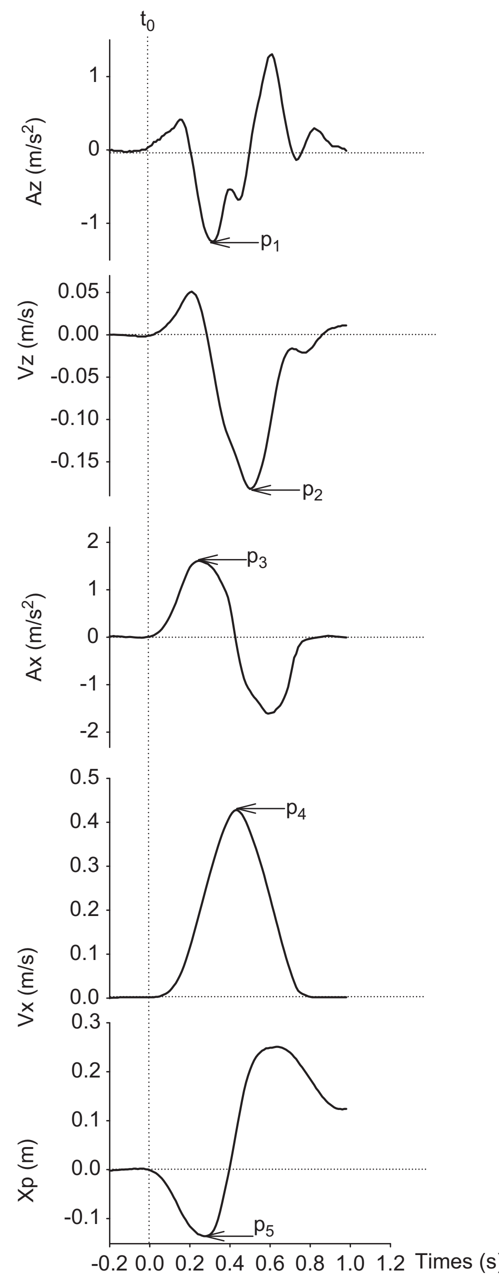

Fig. 2. Biomechanical traces of trunk flexion of one subject. Az, Vz, vertical acceleration and velocity of CoM respectively; Ax, Vx, A/P acceleration and velocity of CoM respectively: Xp, displacement of CoP. Dotted line, zero time (onset of variation of biomechanical traces). P1: peak of vertical CoM acceleration; P2: peak of vertical velocity; P3: peak of antero-posterior CoM acceleration; P4: peak of antero-posterior velocity; P5: maximum backward displacement of center of pressure.