INFLUENCE OF INITIAL PELVIC TILT ON VERTICAL JUMP HEIGHT

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INTRODUCTION
Vertical jumps have been fully studied during the last thirty years. Especially maximal vertical jumps used to be analyzed, which maximal vertical jump height was considered as the main factor of the performance. Maximal vertical jump height depends on effective energy, the sum of potential and “vertical kinetic energy” (i.e. kinetic energy due to vertical velocity) of the body mass center (BMC). Therefore, in order to reach a maximal jump height, it is necessary to increase vertical position of BMC and vertical velocity of BMC as high as possible at takeoff. To understand which patterns individuals use to perform maximal vertical jumps, the body was simplified into a four rigid segment model in the sagittal plane. It was composed of the feet, the shanks, the thighs and the segment “Head-Arm-Trunk” (HAT) and of three joints (ankle, knee, hip) [1]. Muscles crossing these joints would produce work when shortening and would contribute to the increase of height of the BMC during vertical jumps. Nevertheless the HAT segment is not a single rigid segment. Especially the trunk could be divided into the pelvis and the rachis which could be divided into several segments. Therefore it could be hypothesis that hip and trunk muscles crossing these joints, resulting from these several segments, could contribute to the increase of the height of the BMC.

The purpose of this study was to investigate the influence of the pelvic tilt and the trunk contribution on vertical squat jump height.

METHODS
Nineteen healthy athletic male adults (mean ± SD: age, 21.8 ± 2.6 years; height, 1.78 ± 0.05 m; mass, 70.2 ± 9.5 kg; BMI, 21.9 ± 2.1) volunteered to participate in the study and provided informed consent. None of them presented actual or previous pelvic or spinal pathologies.

Prior to the experimental protocol, reflective landmarks were stuck on the left 5th metatarsophalangeal, lateral malleolus, lateral femoral epicondyile, greater trochanter, acromion and posterior superior iliac spine (PSIS). A 10 minutes warm-up, including squat jumps session familiarized participants to the task. Thereafter, the subjects performed randomly three maximal squat jumps with an initial forward pelvic tilt (pelvisF) and with an initial backward pelvic tilt (pelvisB). During the pelvisF condition, the aim was to increase the initial extension of the trunk and limit the work of the trunk extensor muscles. Indeed, when the pelvis is tilted forward, a lumbar hyperlordosis is observed [4]. Therefore the trunk would be close to full extension when pelvis is initially tilted forward. During the pelvicB condition, it was attempt to enable trunk extension and enable the trunk muscle extensors to produce work. Indeed, when the pelvis is tilted backward, a lumbar hyperkyphosis is observed [4]. Thus, the trunk would be overall flexed and could extend during push-off.

All jumps were performed on an AMTI force plate model OR6-7-2000 sampled at 1000 Hz and were filmed in the sagittal plane with a 100 Hz camcorder (Ueye, IDS UI-2220SE-M-GL). Subjects were instructed to keep their hands on their hip throughout the movement. The push-off of the best jump, characterized by the greater height reached during flight, was selected for further analysis.

Jumps recorded were digitalized frame by frame with the Loco® software (Paris, France). A five rigid segments model composed of the foot, the shank, the thigh, the pelvis and the HAT (head, arms, and trunk) was designed. Ankle (θankle), knee (θknee), hip (θhip) and trunk (θtrunk) joints resulted from these segments (figure 1). The pelvic tilt in the sagittal plane was determined as the angle between the thigh and the pelvis (θhip). The smaller this angle, the more the pelvic tilts forward. Otherwise, the greater the angle, the more the pelvic tilts backward. Joint range of motions (RoM) were equal to the difference between the joint angle at takeoff and the joint angle at the beginning of the push-off. The total increase in height of the BMC (Δhtotal) was calculated as the sum of flight height (Δhflight) and the increase in height of the BMC during contact (Δhcontact). Δhflight and Δhcontact were calculated from force plate data by numerical integration (trapezoidal rule). The initial height of the BMC was determined from kinematic data. Segment center of mass was calculated according to Winter’s anthropometric tables (1990).

Figure 1: Five rigid segments model in relation to the sagittal plane.

Effect of initial pelvic tilt on Δhflight, Δhcontact and joint angles were tested to significance with a paired student’s t-test (two-tailed). All analyses were executed using the “R commander package” software (R.2.7.2., R Foundation for Statistical Computing, Vienna, Austria). The level of significance for all tests was set at p < 0.05.
RESULTS AND DISCUSSION

First of all, some conditions needed to be verify to validate the reliability of the results. The initial height of the BMC was almost similar between the two conditions (p = 0.07). The initial Q_{bne} was significantly smaller and Q_{trunk} greater (p < 0.01) when the pelvis was initially tilted forward compared to the pelvisB whereas the initial Q_{knee} remained the same (p = 0.70). These variables validate the initials conditions of the maximal squats jumps.

Knee joint RoM was unchanged (p = 0.35), hip joint RoM was greater during the pelvisF and trunk joint RoM was greater during the pelvisB (p < 0.001). Therefore differences in Gluteus Maximus (GM), Biceps Femoris (BF) and Rectus Femoris (RF) shortening distance between the pelvisB and pelvisF jump were only due to Q_{hip}.

No difference was pointed out between pelvisF Δh_{contact} and pelvisB one (p = 0.22). While pelvisB Δh_{flight} was significantly greater than pelvisF Δh_{flight} (p < 0.05) (Table 1).

Maximal vertical jump height depends on effective energy, depending on potential energy and “vertical kinetic energy” [2]. Therefore, initial pelvic tilt, and consequently trunk motion, would influence “vertical kinetic energy” (i.e. changing Δh_{flight}) but not potential energy at takeoff (i.e. Δh_{contact} remaining unchanged). Then, only Δh_{flight} results will be discussed.

Δh_{flight} depends on vertical velocity of the BMC at takeoff, which is related to the capacity of activated muscles to produce work. Δh_{flight} was improved around 7% during a squat jump performed with a pelvisB (enabling trunk muscle extensors to produce work) compared to pelvisF (minimizing trunk muscle extensors to produce work). Therefore, it was assumed that muscles participating to increase effective energy of BMC produce more work during the pelvisB condition. Nevertheless, initial pelvic tilt would influence trunk muscle work, but also work of the muscles crossing the pelvis. Indeed, the pelvic tilt influences the lengthening of the muscles crossing the hip joint and the pelvis. A pelvisF would lead to a lengthening of the BF and the GM while the RF would be shortened. A pelvisB would lead to a lengthening of the RF whereas the BF and the GM would be shortened [5]. During maximal squat jump the GM is firstly activated leading to the hip extension helped by the BF [1]. Therefore these two muscles contribute to the vertical acceleration of the BMC. Moreover, to maximize the work of activated muscles, the shortening muscle distance should be as large as possible [2]. In our study, the pelvisB condition would imply a reduction of GM and BF shortening distance compared to the pelvisF condition [5]. As a consequence, GM and BF works would become lower during the pelvisB condition. Therefore, Δh_{flight} would be lowered during the pelvisB condition compared to the pelvisF one. Our study indicated opposite results (Δh_{flight} during the pelvisF condition was lower compare to the pelvisB one). Therefore it was hypothesized that the observed positive net effect of pelvisB on Δh_{flight} was due to muscle work of the trunk. This assumption has also been pointed out by some authors, who observed lower jump height with a simulation model, without taking into consideration the work of the trunk muscles, compare to subject data [3].

CONCLUSIONS

Initial pelvic tilt would have an effect on vertical jump height during squat jumping. An initial backward pelvic tilt would improve vertical velocity at takeoff compare to an initial forward pelvic tilt. The positive net effect of the pelvisB could be due to work of trunk extensor muscles. Further studies will aim to quantify the trunk contribution in vertical jump height through a simulation approach.

REFERENCES


Table 1: Mean and standard deviation values of initial BMC height, initial joint positions, joint RoM, flight height (Δh_{flight}) and height contact (Δh_{contact}) during squat jumps with an initial backward and forward pelvic tilt.

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<th>Backward</th>
<th>Forward</th>
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<tbody>
<tr>
<td>Initial BMC height (m)</td>
<td>0.72 ± 0.06</td>
<td>0.73 ± 0.05</td>
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<tr>
<td>Initial Q_{knee} (rad.)</td>
<td>1.79 ± 0.13</td>
<td>1.80 ± 0.17</td>
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<tr>
<td>Initial Q_{hip} (rad.)</td>
<td>2.69 ± 0.23 ***</td>
<td>2.47 ± 0.23</td>
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<tr>
<td>Initial Q_{trunk} (rad.)</td>
<td>1.54 ± 0.20 ***</td>
<td>1.90 ± 0.24</td>
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<tr>
<td>Knee RoM (rad)</td>
<td>1.22 ± 0.14</td>
<td>1.20 ± 0.19</td>
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<tr>
<td>Hip RoM (rad)</td>
<td>0.86 ± 0.17 **</td>
<td>1.01 ± 0.18</td>
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<tr>
<td>Trunk RoM (rad)</td>
<td>0.78 ± 0.17 ***</td>
<td>0.52 ± 0.19</td>
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<tr>
<td>Δh_{flight} (m)</td>
<td>0.30 ± 0.03 *</td>
<td>0.28 ± 0.03</td>
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<tr>
<td>Δh_{contact} (m)</td>
<td>0.36 ± 0.05</td>
<td>0.37 ± 0.05</td>
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* Significant difference between pelvisF and pelvisB (p < 0.05)
** Significant difference between pelvisF and pelvisB (p < 0.01)
*** Significant difference between pelvisF and pelvisB (p < 0.001)