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EFFECT OF PERFORMANCE SPEED ON THE KINEMATICS AND KINETICS OF TWO TRUNK AND HIP STRENGTHENING EXERCISES

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The aim of this work was to study the effect of speed on the sit-up (SU) and leg raising-lowering (LRL) exercise technique. Seventeen subjects volunteered to participate, performing at 3 cadences. Video 3D analysis was conducted and ground reaction forces were record. The anterior-posterior displacement of the centre of pressure (COP) and mean range of motion (ROM) for 6 angles were calculated. Results indicate that when SU speed increases, hip and knee ROM increase, while there is a decrease in the upper trunk flexion. In the LRL there is a decrease in the pelvic tilt and hip angle, and an increase in the knee angle. It seems that in higher speed exercises, subjects modified their technique to keep up with the cadence. Coaches and trainers should control the subjects' technique during the execution of these high speed exercises.

KEY WORDS: pelvic tilt, exercise technique, photogrammetry, force plate.

INTRODUCTION: A large number of biomechanics studies have analyzed different factors of the trunk exercise performance, including spine and hip flexion, trunk rotation and bending, supported segments, arm and hand position, knee and hip position, movement of upper body vs. lower body, and the use of equipment (Monfort et al., 2009). However, scientific evaluation of the influence of performance speed on trunk exercise technique is lacking. The aim of the study was to analyze the effect of performance speed on the kinematics and kinetics of two trunk and hip conditioning exercises: sit-up (SU) and double leg raising-lowering (LRL). Specially, we were interested in identifying variations of the exercise technique caused by speed increase that may affect the training results.

METHODS: Seventeen healthy subjects, 13 female and 4 male (age: 23.58 (4.43) years; height: 166.27 (6.47) cm; mass: 61.00 (8.40) kg) volunteered to participate in this study after signing a written informed consent. They were asked to execute SU and LRL at three cadences controlled by a metronome: 1 repetition/4 s (C4), 1 repetition/2 s (C2), and 1 repetition/1.5 s (C1.5). In all conditions, subjects performed 10 repetitions and the central 5 were analyzed. The conditions were randomly assigned. The subjects' trunk was placed horizontally on a force plate (Dinascan IBV, Valencia, Spain), adjusting their sagittal plane with the longer axis of the plate (figure 1). In the SU subjects had to raise the trunk to touch their knees with their elbows and return to the initial position. In the LRL they had to raise their lower limbs with the knees extended to touch a bar which indicated the vertical position (figure 1). They were instructed to carry out the exercises following the cadence in a constant motion.
Ground reaction forces were recorded during the execution, and the centre of pressure (COP) excursion in the antero-posterior axis was calculated. Simultaneously, a 3D photogrammetric study was conducted. Three digital cameras recording at 50 Hz were placed at 0º, 45º, and 90º from the sagittal plane. The reference frame used was a prism of 2 x 1 x 1 m. A model of 8 points and 6 segments was used to represent the principal joint movements involved (figure 2). The markers were automatically digitized and reconstructed with the software Kwon 3D (Visol Inc., Korea). The following angles were calculated in the sagittal plane for both exercises: dorsal-lumbar flexion (DLF), pelvic tilt (PT), hip (H) and knee (K). For the SU, upper trunk with the horizontal (UTH) and dorsal flexion (DF) angles were also calculated (figure 2).

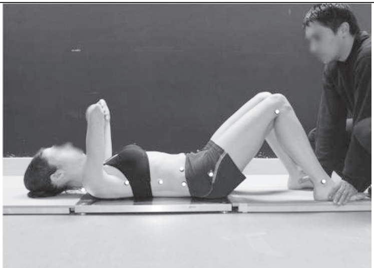
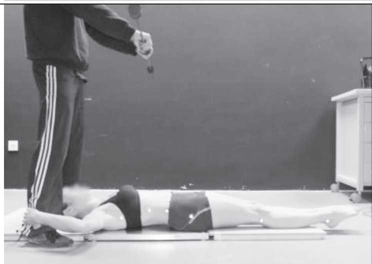
	INITIAL POSITION	**FINAL POSITION**
SIT-UP		
LEG RAISING-LOWERING		

Figure 1: Description of the exercises. Subjects were instructed to move at a constant speed.

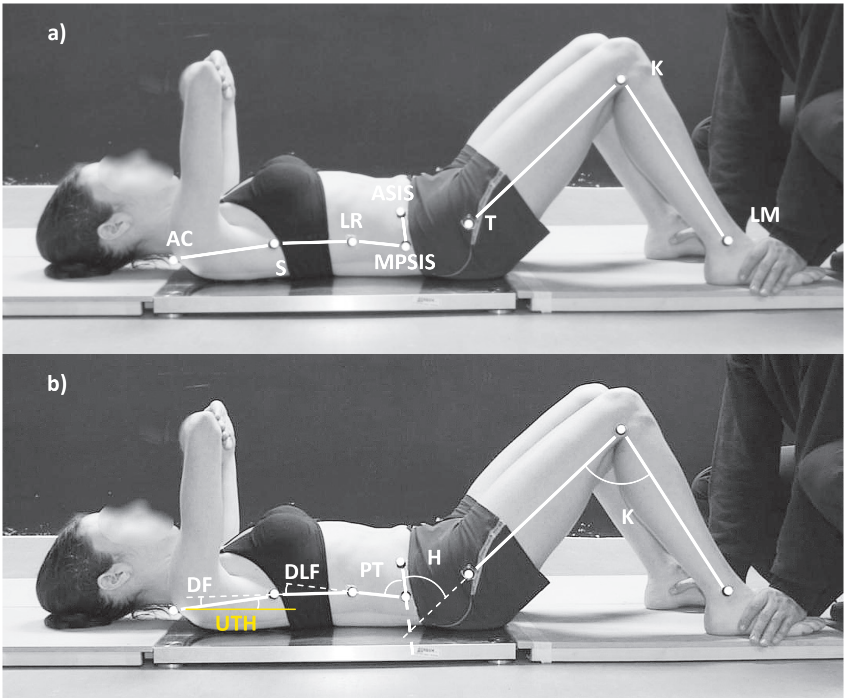


Figure 2: A model of 8 points and 6 segments was used.
a) Anatomical markers: LM- lateral malleolus; K- knee; T- trochanter; ASIS- anterior superior iliac spine; MPSIS- middle of ASIS and posterior superior iliac spine; LR- lower rib; S- inferior angle of the scapula; A- acromion.
b) Measured angles: UTH- upper trunk with the horizontal; DF- dorsal flexion; DLF- dorsal-lumbar flexion; PT- pelvic tilt; H- hip; K- knee.

The mean range of motion (ROM) of each angle at each cadence was measured. In addition, the anterior-posterior COP displacement was calculated from the kinetic data. A repeated measures ANOVA was performed to compare each variable between cadences. The statistical significance was set at $\alpha = 0.05$.

RESULTS: The anterior-posterior COP displacement and the mean ROM of the aforementioned angles for the 5 central repetitions of the SU and LRL are shown in table 1. Results indicate that when speed increased there was an increase in the anterior-posterior COP displacement in both exercises. The ROM of the angles was not modified in the same way in both exercises. In the SU there was a significant increase in the ROM of the hip and knee angle, and a decrease in the ROM of the upper trunk flexion and pelvic tilt angle, although the reduction in the pelvic tilt angle did not reach statistical significance ($p = 0.053$). On the other hand, in the LRL there was a significant decrease in the ROM of the pelvic tilt and hip angle, and an increase in the ROM of the knee angle ($p<0.05$).

Table 1
Angular range of motion and anterior-posterior centre of pressure displacement at each cadence

	C1.5	C2	C4	F	p
Sit-up					
COPx	40.04 (7.42)	35.84 (6.70)^{A}	33.43 (3.99)^{A}	12.838	.000
UTH	99.43 (12.43)	106.80 (10.42)^{A}	107.84 (9.50)^{A}	9.461	.001
DF	19.40 (9.14)	23.17 (8.92)	23.19 (7.04)	2.941	.067
DLF	23.35 (8.70)	24.90 (7.97)	23.64 (8.14)	0.758	.443
PT	30. 41 (9.18)	31.30 (7.00)	33.86 (7.17)	3.214	.053
HIP	42.59 (8.35)	39.86 (7.71)^{A}	37.59 (6.79)^{AB}	14.519	.000
KNEE	16.20 (2.97)	15.02 (3.48)	12.77 (3.71)^{AB}	15.307	.000
Leg raising-lowering					
COPx	35.14 (3.69)	26.37 (3.58)^{A}	21.55 (2.90)^{AB}	156.241	.000
DLF	12.92 (5.42)	11.12 (4.75)	10.93 (5.11)	3.374	.065
PT	28.78 (8.62)	31.17 (7.57)^{A}	31.72 (8.02)^{A}	6.061	.006
HIP	55.62 (8.02)	58.47 (9.57)^{A}	58.30 (8.63)^{A}	9.031	.001
KNEE	19.86 (12.37)	14.68 (7.12)^{A}	11.42 (5.64)^{AB}	9.565	.004

Cx- cadence, where x is the number of seconds to complete each repetition; COPx- anterior-posterior centre of pressure displacement; UTH- upper trunk with the horizontal angle; DF- dorsal flexion angle; DLF- dorso-lumbar angle; PT- pelvic tilt angle; HIP- hip angle; KNEE- knee angle.
COPx is expressed in centimetres, angular range of motions are expressed in degrees.
^{A}Significantly different from C1,5 ($p < .05$); ^{B}Significantly different from C2 ($p < .05$). Bonferroni adjustment was used for multiple comparisons.

DISCUSSION: A common problem in sports and exercise is to control the intensity of the exercises. One of the variables that can be easily manipulated to modulate the intensity of the trunk exercises is the speed of movement (Vera-Garcia et al., 2008). In addition, training effects are specific to performance velocity (Kanehisa & Miyashita, 1983), and consequently some sports require high exercise speeds and plyometrics to improve performance (McGill, 2006).

In the present study, the effects of performance speed of two conventional trunk and hip strengthening exercises were analyzed. It was expected that the increase in angular momentum due to the higher speed would create an increase in the trunk motion. This is supported by the significant increase in the COP displacement in both exercises (table 1). However, in the ROM of the angles there were different effects depending on the exercise. In the SU, as speed increased the hip and knee ROM also increased, possibly because in most subjects the trunk displaced away from the feet during higher speed exercises. The subject

finished the exercise with a higher lower limb extension, and therefore a different muscular activation pattern could have occurred. Increasing the friction with the ground is recommended to avoid trunk slipping during this exercise at high speeds. In relation to the trunk flexion, there was no change in the strategy used to raise the trunk from the force plate (commonly: first a curl up of the upper trunk, followed by a hip flexion), since the ROM of the DF and DLF angles did not change (table 1). Nevertheless, a reduction in the amplitude of the UTH ROM was found, which may be due to a reduction in the downwards movement of the trunk and head at the end of each repetition with the intention of following the rhythm at the higher cadences.
Surprisingly, the speed increase in the LRL reduced the pelvic ROM. This could be interpreted as a result of an increase in the trunk muscle coactivation, which in many cases could be a desired effect (Vera-Garcia et al., 2006 & 2007). But this should be taken cautiously because simultaneously there was a reduction in the hip ROM and an increase in the knee ROM (more flexion when it should be constantly extended). This is also interpreted as a modification of the exercise technique to reduce the radius of gyration and so the angular momentum, facilitating the objective of following the higher cadences.

CONCLUSION: The results indicate that the exercise technique changes when the speed of movement increases. Most of these changes seem to be due to the subjects' difficulty to keep up with the higher exercise cadences. Sport and exercise professionals should bear this in mind when using these exercises at high speeds, and continuously correct the athletes' modifications of the technique.

REFERENCES:

Kanehisa, H. & Miyashita, M. (1983). Specificity of velocity in strength training. *European Journal of Applied Physiology and Occupational Physiology*, 52, 104-6.

McGill, S.M. (2006). *Ultimate back fitness and performance*. 2nd ed. Waterloo, ON, Canada: Wabuno Publishers.

Monfort-Pañego, M., Vera-Garcia, F.J., Sánchez-Zuriaga, D. & Sarti-Martínez, M.A. (2009). Electromyographic studies in abdominal exercises: a literature synthesis. *Journal of Manipulative and Physiological Therapeutics*, 32(3), 232-44.

Vera-Garcia, F.J., Flores-Parodi, B., Elvira, J.L. & Sarti, M.A. (2008). Influence of trunk curl-up speed on muscular recruitment. *Journal of Strength and Conditioning Research*, 22(3), 684-90.

Vera-Garcia, F.J., Brown, S.H.M., Gray, J.R. & McGill, S.M. (2006). Effects of different levels of torso coactivation on trunk muscular and kinematic responses to posteriorly applied sudden loads. *Clinical Biomechanics*, 21, 443-55.

Vera-Garcia, F.J., Elvira, J.L.L., Brown, S.H.M. & McGill, S.M. (2007). Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. *Journal of Electromyography and Kinesiology*, 17, 556-67.

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