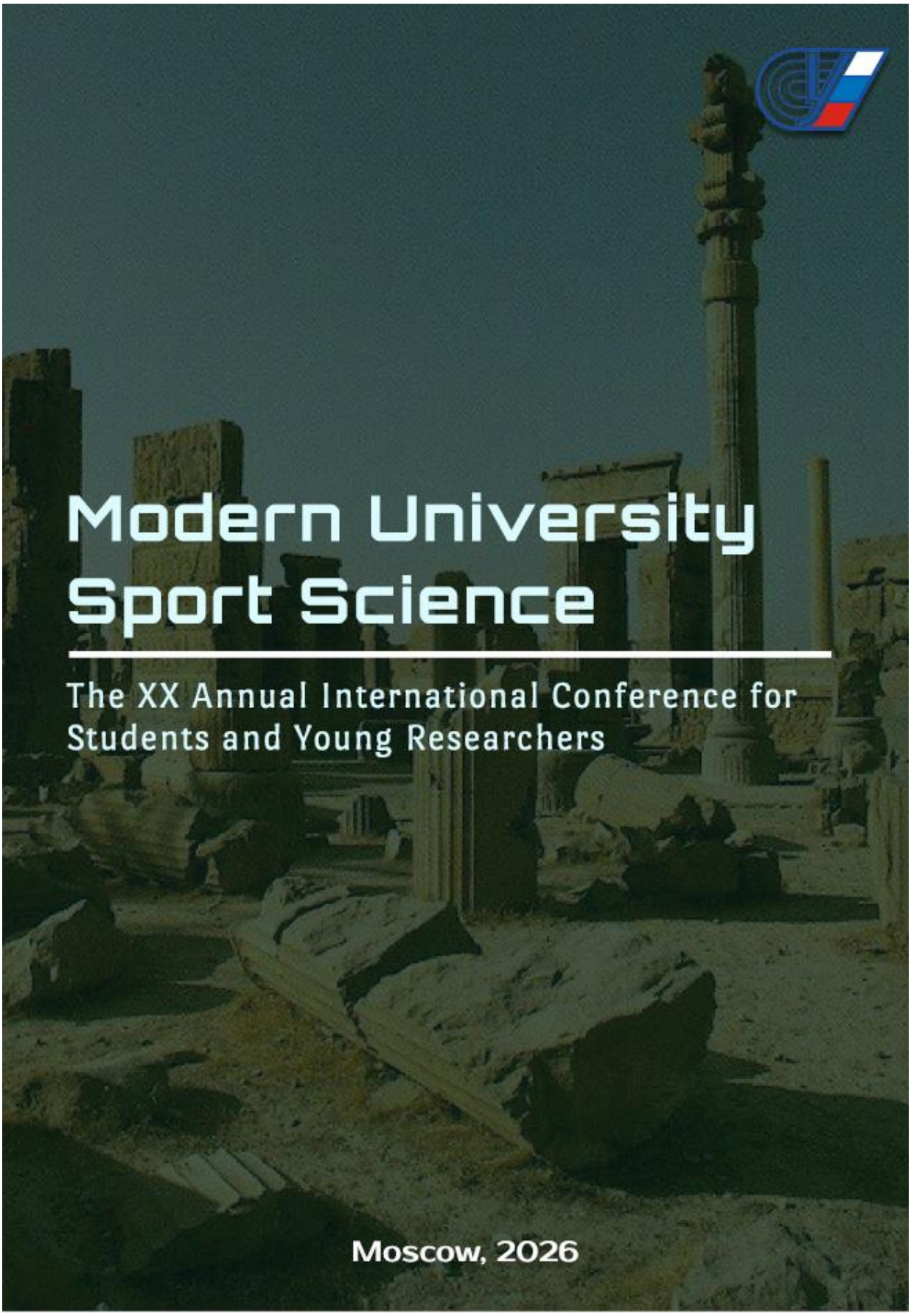

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WHAT ARE THE CURRENT CHALLENGES IN TESTING ATHLETES' BALANCE?

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Abstract. *Neuromuscular control of postural and core stability is essential for effective functional athletic movements. Although exercises to improve balance and core performance are well known, their assessment in sport-specific conditions is lacking. This work provides an overview from the most widely used traditional methods of balance assessment to novel methods that simultaneously assess postural and core stability with respect to the specific requirements of athletes.*

Keywords*: center of mass, center of pressure, dynamic balance tests, static balance tests, perturbation-based balance tests, task-oriented balance tests*

Introduction.

Traditionally, postural stability has been assessed using stabilographic systems based on the measurement of vertical-ground reaction forces using a force plate and the calculation of the center of pressure (CoP). However, this method does not actually measure the movement of the body's center of gravity. So, it's actually postural stability that's being assessed, not core stability.

Using 3D motion analysis, it is now possible to extract the center of mass (CoM) movement. However, such diagnostic systems are relatively expensive, time-consuming for the measurement itself and subsequent data analysis and are mainly used in laboratory conditions. User-friendly, portable, and inexpensive

diagnostic systems are more suitable for field testing. Although estimating the CoM trajectory is a bit challenging, body sway can be measured using wireless inertial sensors attached to the trunk. Such indirect core stability testing can be used alongside traditional postural stability tests in both the general population and athletes.

Static balance tests

Static posturography is usually used for assessing postural stability in athletes of various sports specializations [1,2], in response to various forms of exercise [3], as well as adaptive changes after various exercise programs [4]. However, this method is not sensitive enough in most cases to distinguish balance performance in highly skilled athletes. Lower sensitivity of static posturography is a consequence of multiple sensory inputs (visual, vestibular, and proprioceptive) involved in postural control. Such a system can compensate for a smaller impairment of balance in such a way that under normal conditions (stance on a stable surface) no deficits in postural stability may be apparent. Under dynamic conditions (stance on an unstable surface), the control mechanisms are taxed to a substantially higher extent so that individual differences can be revealed.

Therefore, the combination of various testing conditions should be used to increase the demands on postural control system. These include different surfaces (firm force plate, foam placed on a force plate, spring-supported platform), stances (bipedal, unipedal), feet position (semi-tandem, tandem), knee and hip angles (weight-bearing-leg: knee fully extended, knee flexed 10-20°; non-weight-bearing leg: knee flexed 90°, hip flexed 0° or 45°), arms position (at the side, crossed over the chest, fixed on the hips), visual inputs (eyes open, eyes fixed on a stationary target, eyes closed), and so forth.

Experience indicates that standing on an unstable foam surface, wobble board or a spring-supported platform while testing body balance is more efficient in discriminating within-group and between-group differences when compared to static balance tests. Assessment of balance under unstable conditions, coupled with or without visual references, is also able to reveal slight changes in the postural control throughout the lifespan and/or after exercise programs focused on improvement of sensorimotor functions. Postural stability testing while standing on an unstable platform should be preferred over static balance tests even in highly skilled athletes.

Dynamic balance tests

In sports, where the ability to maintain balance on various unstable surfaces is one of the limiting factors of performance, the dynamic posturography represents more specific and hence more appropriate alternative for the assessment of balance than systems allowing for monitoring of the CoP variables in static conditions. Usually, external perturbations from a platform either shifting in antero-posterior and medio-lateral direction or tilting the toes up and down; or

applying them directly to the body by pushing/pulling the trunk, the shoulders or pelvis are used.

We have found that postural and trunk responses to unexpected perturbations depend on the velocity and direction of platform motion [5]. Specifically, the velocity of perturbation alters peak CoM velocity rather than the magnitude of CoM displacement. The effect of the direction of perturbations on the trunk response emerges only at a high velocity of platform motion, such that the peak CoM velocity and peak CoM acceleration are significantly greater in the anterior than posterior direction.

Most of these laboratory dynamic posturography systems are used primarily in clinical or rehabilitation settings but only partially meet the needs of balance assessment under sport-specific conditions. The practice implies that computerized portable devices that are more applicable to routine testing in the sporting field are preferred over laboratory techniques.

Perturbation-based balance tests

Instrumented tests such as trunk repositioning and load release tasks which are quick-to-administer, could serve as a possible alternative to overcome above mentioned limitations [6]. The trunk repositioning tasks require a subject to actively or passively return to a neutral spine position following a predefined displacement. Load release tasks require the subject to perform an isometric trunk contraction at a predefined intensity against an external load, which is subsequently released, and the displacement of the trunk is quantified. The voluntary surface electromyography can be recorded from the core musculature to examine the on–off activation of muscles following release.

Specifically, the release of the load produces a sudden change in the external forces acting on the subject, leading to a small anterior and then a larger posterior displacement of the subject's CoP. The perturbation after the load fall causes only a postural sway response, i.e. the subject does not need to take a step to maintain balance. The perturbation is quantified by the maximal anterior and posterior displacement after the load drop.

Task-oriented balance tests

Another alternatives are tests based on visual feedback control of body position [7]. Subjects can perform a visually-guided CoM tracking task or a visually-guided CoM target-matching task. In the first test, subjects are provided with feedback on the CoM displacement on a computer screen while standing on a force plate. Their task is to trace, by shifting their CoM, a curve flowing either in horizontal direction (regulation of CoM movement in Y-axis) or vertical direction (regulation of CoM movement in X-axis). The deviation of an instant CoP position from the curve is recorded. In the second test, subjects hit a target that randomly appears in one of the corners of the screen by horizontally moving the CoM in the appropriate direction, while standing on a spring-supported platform equipped with a computer system used for feedback monitoring of the CoM movement.

A moderate correlation between parameters of these task-oriented balance tests and the common variance of 13% indicates that they assess distinct qualities. This is because voluntary feedback control of body position is performed under different conditions, i.e. the subject is focused either on the goal of the task (i.e. hitting the target) or on movement itself (i.e. the positioning of the CoM). These test differences allow assessment of accuracy of regulation of body movement that requires less or more feedback processing.

The reliability of task-oriented balance tests is comparable to static balance tests, but with better potential to distinguish between groups with different levels of postural control and to detect subtle changes after exercise programs. Providing visual feedback in more demanding conditions (i.e. the stance on a spring-supported platform) enhances discriminatory accuracy of a visually-guided CoM tracking task.

Utilizing techniques based on motion analysis or accelerometry recordings while evaluating head, limb and trunk movements could provide additional data for functional assessment of balance in athletes. The use of trunk accelerometry is a cost-effective and easily applied solution for measuring body balance and human movement. With the advent of fwireless technology and low-cost accelerometers, their use in the field-testing of various aspects of balance is now feasible. In all the above-mentioned cases, it is possible to indirectly measure the CoM movement simultaneously using inertial sensors attached to the torso in the region of the estimated body center of gravity in both traditional (Fig. 1) and sport-specific conditions (Fig. 2).

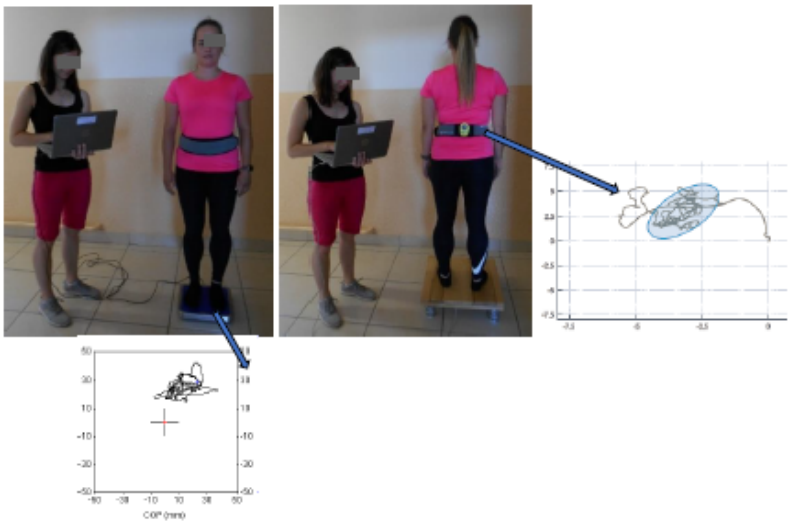

Figure 1 - CoP and CoM registration while standing on a stable force plate and spring-supported platform

Figure 2 - Registration of body sway while slackline walking

Conclusion

This work presents a new approach to CoM movement testing in addition to traditional CoP registration. It can be applied to various tests such as static balance tests, dynamic balance tests, perturbation-based balance tests, and task-oriented balance tests, both in general laboratory and sport-specific settings.

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