Entropy Measures Detect Changes in Movement Variability: Sliding across a Novel Slide Vibration Board in Ice Hockey Players

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1 OBJECTIVES

Slideboard (SB) exercise is a multifaceted, closed kinetic chain that imparts low-impact forces to the lower extremities and is used to enhance strength, endurance, proprioception, agility, balance, body composition, and cardiorespiratory fitness (Diener, 1994; Weber and Ware, 1998). Additionally, based on previous research we can use the SB exercise as a specific and practical off-ice test to evaluate performance in speed skating, prescribe exercise training and monitor adaptations due to training programs (Piucco *et al.*, 2016, 2017).

Apart from this, there is an emerging profile of application of vibration as an exercise modality that is mostly practiced as whole body vibration (WBV), i.e. while standing on oscillating or synchronously platforms and it is now seen as potentially beneficial in certain areas of sports, exercise, rehabilitation and preventive medicine (Rittweger, 2010).

In both issues, either in off-ice hockey training in ice hockey players (Boland *et al.,* 2017; Boucher *et al.,* 2017; Peterson *et al.,* 2016) as in WBV in elite athletes (Hortobágyi *et al.*, 2015), specific tasks are recommended. In this way, although several studies have analysed both SB and WBV separately, no studies have been found with a Slide Vibration Board (SVB). Moreover, the studies analysed in metabolic, electromyographic and performance parameters, but no studies have used non-linear analyses.

In the same way, from constraint-led approaches, an additional category of experiments conducted to date has manipulated the environment. Increasing environment complexity or motor behaviour can be seen as environmental constraints since the performer has to adapt in order to perform successfully (Rienhoff *et al.*, 2016). In this sense, WBV while sliding upon a SB could led us to improve specificity and develop challenging training environments, which increases movement variability and adaptability (Button *et al.,* 2006) using WBV as a environment constraint.

To evaluate the effect of constraint in non-linear terms is important, because when assessing measures from complex systems such as human movement, there are components that can provide insight into the underlying nature of the system (McGregor and Bollt, 2012).

What is yet unknown, is how these constraints affect the dynamics of kinematic variables and, ultimately, the performance outcomes. The conventional approaches that describe variability using linear measures, provide very limited information about how the motor control system responds to changes, either within or between individuals (Stergiou, 2016).

In movement variability assessment, entropy is among the most popular and promising complexity measures for biological signal analyses (Gao *et al.,* 2012). When considering time series data variables, describing agent interactions in social neurobiological systems, measures of regularity can provide a global understanding of such systems behaviours. Sample Entropy (SampEn) analysis has become relatively popular as a measure of system complexity. It has been used to describe locomotive movements and manipulations in resistance training, using the acceleration signal as a non-invasive tool to assess training status (Murray *et al.*, 2017; Moras *et al.*, 2018).

Thus, from a non-linear perspective, when using tools like entropy, the functional variability of athletes during the performance of a movement must be perceived as a key element to identify the amount of perturbation in task constraints (Couceiro *et al.*, 2013).

Therefore, the aim of this study was to compare the effect of WBV as an environment constraint (VEC) and without vibration (NV) when performing an slide exercise across SVB using SampEn analyses.

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2 METHODS

Ten elite ice hockey players from a professional team at the Spanish national league volunteered to participate in this study (mean ± *SD*: age 20.4 ± 2.07 years, height 1.79 ± 0.05 m, weight 75.97 ± 5.44 kg). The procedures of this study complied with the Declaration of Helsinki (2013) and were approved by the local ethics committee "Comitè d'Ètica d'Investigacions Clíniques de l'Administració Esportiva de Catalunya" (06/2018/CEICGC).

The study was conducted on a 2m synchronously slide vibration board (SVB) (Patent, P201630075). SVB provide three frequencies: 20, 25 or 32 Hz and a 2mm amplitude with no choice. For the VEC condition, the frequency selected was 32 Hz and the amplitude was 2mm, which are in the range that have been reported in the literature (frequency, from 20 to 50 Hz; and amplitude, from 2 to 10 mm) (Di Giminiani *et al.*, 2013). Participants were instructed to refrain from heavy exercise in the 24 h before each test, and to abstain from the ingestion of stimulants (i.e, caffeine, nicotine) or alcohol. The study was carried out on three days separated by six to eight days. On the first day**,** players underwent a familiarization session with the SVB. On the second and third day**,** each player performed one sliding test, under VEC or NV randomly. The experimental protocol began with a standardized warm-up, after which, 1 bout of 1 minute under VEC or NV was performed. The cadence was 30 push-offs per minute (ppm) and was controlled by metronome (Korg KDM-3 Digital Metronome, Tokyo, Japan), in order to avoid confusion variables.

Throughout each exercise trial, trunk acceleration of the ice hockey players under both conditions (VEC and NV) was measured using a wireless inertial measurement unit (WIMU, Realtrack Systems, Almeria, Spain), a 3D accelerometer 100G recording at 1000 Hz. The accelerometer was attached to the player using an elastic waist belt closed to the sacrum. This position provide the best indication of whole body movement, as the location is close to the player's center of mass (Montgomery *et al.,* 2010). SampEn were calculated in arbitrary units (a.u.) using the module of the acceleration signal (Moras *et al.*, 2018).

Data analyses were performed using PASW Statistics 21 (SPSS, Inc., Chicago, IL, USA). Normality was assessed using the Shapiro-Wilk test. The level of statistical significance was set at $p < .05$ and the confidence interval of the difference was set at 95%. Data are expressed as mean SampEn (a.u.) ± standard deviation. SampEn were analysed using a paired-samples t-test to compare variables between VEC and NV protocols.

3 RESULTS

The SampEn values for the ice hockey players were 0.07 ± 0.02 and 0.19 ± 0.08 for the NV and the VEC conditions, respectively (Figure 1). There was significantly higher entropy performing the VEC protocol (0.13 ± 0.08 p = 0.001). The lower and upper confidence intervals for the difference were -0.18 and -0.07 respectively.

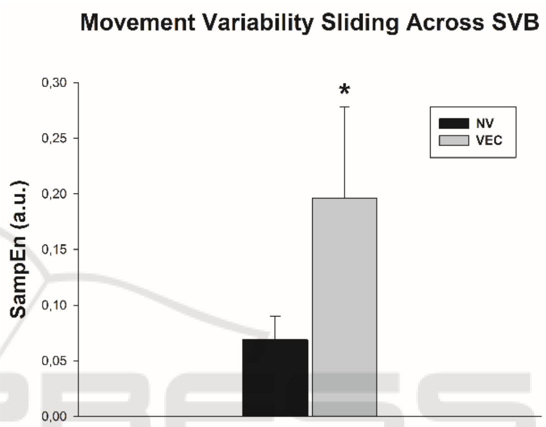

Figure 1: Significantly differences p = 0.001 were found performing slide exercise adding VEC.

4 DISCUSSION

This study aimed to identify the differences in the structure of variability of acceleration signal when performing slide exercise (NV) adding VEC across SVB to establish the amount of perturbation.

The main findings suggest that the vibration constraint increase the structure of variability of acceleration signal produced by the players.

Although this is the first work to assess the acceleration while sliding across a SB with a vibration constraint, slower performance in constrained tasks by hockey sticks has previously been reported in field hockey players (Wdowski and Gittoes, 2013). More recently, increasing SampEn were found in the structure of variability in body acceleration when introduce specific ball constraints (Moras *et al.*, 2018).

Thus, the vibration constraint applied to the SVB exercise affects the players during sliding performance and may indicate detrimental movement control or coordination when a vibration constraint is added. The perturbation showed under VEC could be explained because on WBV platforms the body loses contact with the ground and becomes air-bound, due to the lack of a firm attachment (Rittweger, 2010). These results suggest that SB training could integrate vibration constraints in training protocols in order to reach constraint-led approach as we mentioned above.

The SampEn values increase in the VEC for all players. These results indicate that the constraint applied to the SB exercise induces a change in system coordination patterns or establishes certain combination of movement stability and adaptability (van Emmerik and van Wegen, 2002). This is an evidence of how specificity issues can foster the adaptive aspects of movement variability. The association of the degree of variability with skill and health is changing (Hamill *et al.*, 1999) It has been shown that some degree of motor variability is beneficial as it allows a more adaptive system to internal and external perturbations that constantly act on the body.

To conclude, the use of VEC across SVB for ice hockey players elicits different structure of variability in body acceleration. Thus, ice hockey players might benefit from performing constrained environment tasks across SVB. Understanding constraints and its motor adaptations may help coaches and trainers to enhance the effectiveness of training.

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