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Body size and countermovement depth confound relationship between muscle power output and jumping performance

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ABSTRACT

A number of studies based on maximum vertical jumps have presumed that the maximum jump height reveals the maximum power of lower limb muscles, as well as the tested muscle power output predicts the jumping performance. The objective of the study was to test the hypothesis that both the body size and countermovement depth confound the relationship between the muscle power output and performance of maximum vertical jumps. Sixty young and physically active males were tested on the maximum countermovement (CMJ) and squat jumps (SJ). The jumping performance (H_{max}), peak (P_{peak}) and the average power output (P_{avg}) during the concentric phase, countermovement depth (only in CMJ) and body mass as an index of body size were assessed. To assess the power-performance relationship, the correlations between H_{max} with both P_{peak} and P_{avg} were calculated without and with controlling for the effects of body mass, as well as for the countermovement depth. The results revealed moderate power-performance relationships (range $.55<r<.64$) that were comparable for CMJ and SJ jumps. When controlled for body mass, the same values were markedly higher ($.61<r<.82$; $p < .05$ for P_{peak} of both jumps). When controlled for both the body mass and countermovement depth, CMJ revealed $r = .88$ and $r = .77$ for P_{peak} and P_{avg}, respectively. Both jumps revealed stronger relationships with

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P_{peak} than with P_{avg} ($p < .05$) when controlled for either body mass or both body mass and countermovement depth. We conclude that both body size (in CMJ and SJ) and countermovement depth (in CMJ) confound the relationship between the muscle power output with the performance of maximum vertical jumps. Regarding routine assessments of muscle power from jumping performance and *vice versa*, the use of CMJ is recommended, while P_{peak}, rather than P_{avg}, should be the variable of choice.

1. Introduction

Power is typically defined as a rate of performing mechanical work, or a product of force acting upon an object and the object's velocity. Studies of muscle mechanical properties have often explored the ability of isolated muscles and muscle groups to exert power under various mechanical conditions (Cormie, McGuigan, & Newton, 2011a; Kaneko, Fuchimoto, Toji, & Suei, 1983; McMahon, 1984). However, since only external forces directly affect movements, the studies of human movements typically assess the power output produced in actions of the muscular system upon external objects, such as the ground and other external supports, added weights, etc (Nedeljkovic, Mirkov, Bozic, & Jaric, 2009; Samozino, Rejc, Di Prampero, Belli, & Morin, 2012). It has been generally accepted that the performance of ballistic movements depends upon the maximum power that our muscular system can exert under the given mechanical conditions (Bobbert, 2012; Cormie, McGuigan, & Newton, 2011b; Samozino, Morin, Hintzy, & Belli, 2010).

Maximum vertical jumps have not only been one of the most often applied movements in training and testing of particular physical abilities (Cormie et al., 2011b; Cronin & Sleivert, 2005; Markovic, Dizdar, Jukic, & Cardinale, 2004), but also a frequent model for studying the fundamental properties and phenomena related to the human locomotor system (Jaric & Markovic, 2009; Markovic & Jaric, 2005; Samozino et al., 2010, 2012). Therefore, the relationship between the jumping performance and the associated muscle power has been of particular importance. Specifically, the performance of various types of maximum vertical jumps have often been used to assess the maximum power of the lower body musculature. A number of authors have argued that the tested height of maximum vertical jump (H_{max}) is a valid measure of the maximum power output of lower limb muscles (Baker, Nance, & Moore, 2001; Markovic & Jaric, 2007b; Samozino, Morin, Hintzy, & Belli, 2008). Conversely, muscle strength and power have been routinely considered as valid predictors of jumping performance (Baker et al., 2001; Cronin & Sleivert, 2005). However, a possible effect of body size on the discussed power-performance relationship has been mainly neglected. For example, both the scaling models and most of the experimental data suggests that the muscle power output increases with body size, while the performance of rapid movements (such as H_{max}) could be relatively independent of body size (Astrand & Rodhal, 1986; Jaric, 2003; Markovic & Jaric, 2004; McMahon, 1984). This concept has been supported by findings revealing that the H_{max} could be a measure of muscle power output normalized for body size (Harman, Rosenstein, Frykman, Rosenstein, & Kraemer, 1991; Markovic & Jaric, 2007a; Nedeljkovic, Mirkov, Markovic, & Jaric, 2009). However, the discussed effect of body size has yet to be properly quantified. Namely, due to a relatively narrow range of human body sizes (Jaric, 2003; Markovic & Jaric, 2004; McMahon, 1984), the discussed effect may not be strong enough to play a meaningful role in routine assessments of muscle power output from the tested jumping performance, and *vice versa*.

In addition to the body size, one could argue that the jumping technique could also confound the discussed power-performance relationship of vertical jumps. For example, it is well known that the depth of the preceding countermovement can vary within a wide range in the natural maximum vertical jumps (Cormie, McGuigan, & Newton, 2010; Markovic & Jaric, 2007b; Markovic, Mirkov, Knezevic, & Jaric, 2013). Increased countermovement depth reduces the leg extension angles and leg stiffness, which inevitably decreases the ground reaction force due to a lower leverage of the leg extensor