



How Can The Training Load Be Adjusted Individually in Athletes with An Applied Statistical Approach?

João Gustavo Claudino^{1,2*}, John Barry Cronin^{2,3}, Alberto Carlos Amadio¹, Julio Cerca Serrão¹

Abstract

Individually adjusting the training load of athletes is of undeniable importance, in optimizing adaptation and performance gains; however, this individualized approach has been a challenge for coaches especially in team sports. The countermovement jump (CMJ) height has been one of the most used measurements for monitoring neuromuscular status in high performance athletes. For this, the true score is essential when monitoring an individual's "real" performance change i.e. greater than the typical error of measurement (TEM). The purpose of the present study is to describe how the minimal individual difference (MID) can be calculated and applied by researchers and practitioners. It is important that the athlete is familiarized with the countermovement jump (CMJ) as the desired outcome is for the athlete to achieve equivalency in CMJ height scores over two days. As a result of the familiarization process the TEM associated with the CMJ is reduced. For reliability testing, the athlete performs 8 CMJs each day and with this data, the MID is calculated via an excel spreadsheet. The average of the 8 jumps of the second day of reliability testing is considered as the participant's baseline. Thus, researchers and practitioners can use the MID of CMJ to monitor neuromuscular status and regulate individual training loads.

Keywords

Assessment; Measurement; Reliability

Introduction

It is necessary to monitor and regulate training load to ensure that planned performance gains are actualized and the likelihood of non-functional overreaching is mitigated [1,2]. Thus, being able to determine whether workloads are appropriate is pivotal in ensuring adaptation is optimal and sustained. This is achieved by sport coaches monitoring the neuromuscular status of their athletes [3,4], and regulating the training loads [5,6] to optimize the balance between training and recovery. In this regard, countermovement jump (CMJ) height has been one of the most used measurements for monitoring neuromuscular status in high performance athletes [3,4,7-27]. Usually the highest jump of three CMJs has been used to monitor the responses to specific training loads [7]. However,

researchers have found that the highest jump did not have adequate sensitivity to detect fatigue during the competition phase whereas the average CMJ height was found sensitive [22]. Fundamental then to monitoring performance is the utilization of best performance or averaged data. Hetherington [28] discussed this issue posing the question whether experimenters should utilize best or average scores in the measurement of physical performance? He concluded that when measurement error was small compared to the within-subject variation, there may be a case to use best performance data as it might predict the true score. The same question has recently received research interest from Al Haddad, Simpson and Buchheit [7] the authors concluding from the data set they investigated (102 highly trained Under 13 and Under 17 footballers) that utilizing averaged or best performance data "likely" provides similar outcomes. However, authors of a recent meta-analysis found that the average CMJ height was more sensitive than highest CMJ height to monitor changes in neuromuscular status [29].

It is the belief of these authors that the use of averaged data should be the preferred method to monitor performance, the use of the highest jump to track training load response having some limitations. For example, highest performance data does not allow the calculation of the individual's typical error of measurement and the respective confidence intervals, hereafter called the minimal individual difference (MID) [1,2]. Furthermore, using the highest jump to track neuromuscular status reduces the odds of finding the true score, because, each observed score is composed of the true score and error [28,30,31]. It should be remembered that sources of error include biological variability (e.g. individual or tester) and technological variability (e.g. instrumentation) [28,30,31]. Irrespective of the source of error, utilizing the highest jump would seem problematic, as researchers have stated that the average height of the CMJ should be used, because humans are able to achieve maximum power/strength in only 5% of their attempts [32]. Using the average height to track neuromuscular status increases the odds of finding the true score to ~50% and when the average plus one standard deviation are used, the odds of finding the true score are increased to 68% [33].

Understanding and determining the typical error associated with a movement is fundamental, particularly when monitoring an individual's "real" performance change i.e. greater than the typical error associated with the measurement [30,34]. The calculation of the individual's typical error of measurement and the respective confidence intervals, termed the MID, may provide a more sensitive (i.e. with 95% odds) means to detect the individual's "real" performance [5]. Thus it may better track overreaching/overtraining and hence monitor and regulate training [1,2]. This individual adjustment of the training load for the athletes is of undeniable importance; however, this individualized approach has been a challenge for coaches mainly in team sports [35, 36]. Nevertheless, the MID of CMJ height has been emerging as a potential tool for this purpose in team sports athletes [37]. However, in our previous studies the MID was calculated using an ANOVA, where the typical error is the "mean square of error", and perhaps such calculations are somewhat complex for the daily routine of researchers and practitioners [5,37]. With this methodological contention in mind, the purpose of this paper is to describe how the MID can be calculated and applied by researchers and practitioners using a simple methodological approach.

*Corresponding author: João Gustavo Claudino, Laboratory of Biomechanics, University of São Paulo, Professor Melo Moraes Avenue 65, Cidade Universitária, São Paulo, Brazil, Tel: +55 (11) 3091-3184; E-mail: claudinojgo@usp.br

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Methods

First the participants need to be familiarized with the CMJ and the reliability of the jump performance determined so as the MID can be quantified. CMJ height can be quantified using field-based equipment such as yardsticks or contact mats and laboratory equipment such as a force plate.

Then, two reliability sessions are conducted. The CMJ protocol consists of 8 jumps with 60-seconds rest between each repetition. The CMJ is initiated from a standing position. Participants are instructed to keep their hands on their chest or hips so as technique is controlled and the influence of arms minimized. They are also instructed to fully extend at take-off and land in a similar manner, and freely determine the amplitude of the countermovement in order to avoid changes in jumping coordination [38].

Jump height is calculated from the equation 1:

$$h = g \times t^2 \times 8^{-1} \quad (1)$$

The participants are encouraged to jump as high as possible for all repetitions and receive their jump height after each repetition [39]. The average of the 8 jumps of the second day of reliability testing is considered as the participant's baseline.

Given the data collected as described previously, it is possible to calculate each individual's typical error of measurement and the respective confidence intervals in an excel spreadsheet. To calculate the typical error of measurement the values of the difference scores (i.e. the difference between reliability sessions for the 8 jumps performed on Day 1 and Day 2) is used for each participant. The standard deviation of individual's difference score (SD_{diff}) is then calculated (Table 1).

Then, simply divide the standard deviation of the difference score by $\sqrt{2}$ to give the typical error of measurement (TEM) [30,31,40]. Previously we have used 95% confidence intervals (95%CI) [5,37], however, according to Hopkins [41,42], it is too conservative for practical significance and he has suggested 90%CI. Hence, the TEM is multiplied by 1.761 to establish the 90%CI according to the distribution of probability for t(14) as $p < 0.10$ i.e. degrees of freedom (DF); $DF \Rightarrow n-1 \Leftrightarrow 8-1=7 \times 2 \text{ days} \Leftrightarrow t(14)$. The workings of this are demonstrated in Equations 2 and 3.

$$[(SD)_{diff} \Rightarrow 1.0 \text{ cm} \div \sqrt{2} = 0.7 \text{ cm} \Leftrightarrow TEM = 0.7 \text{ cm} \quad (2)$$

$$MID \Rightarrow 0.7 \times 1.761 = 1.2 \text{ cm} \Leftrightarrow MID = 1.2 \text{ cm} \quad (3)$$

In the monitoring/regulation process, as required (e.g. daily, bi-weekly, weekly, etc.), the participants should perform a sequence of 8 CMJs, after their standard warm-up at the same time of day. The CMJ average performance that was calculated in the pre-training evaluation is used as a threshold value for loading, maintaining or unloading in the ensuing weeks. As illustrated in Figure 1, an increase in jump height loading is only considered when the difference between the first session's performance of the week, i.e. mean \pm standard error of mean ($SEM = SD \div \sqrt{8}$), and the pre-training performance is positive and greater than the MID (e.g. first session's performance of the week = 32.8 ± 0.6 cm; pre-training performance = 30 cm; MID = 1.2 cm). This is not to say that the coach may make a decision to impose a maintenance or unloading phase, depending on a number of factors e.g. taper, overreaching. For cases in which the difference is the same as the MID value, the athlete performance is considered stable (e.g. first session's performance of the week = 31.5 ± 0.6 cm; pre-training

performance = 30 cm; MID = 1.2 cm). A decrease in loading is considered when the difference between the first session performance of the week (mean \pm SEM) and the reference performance is negative and inferior to the MID (e.g. first session's performance of the week = 27.0 ± 0.6 cm; pre-training performance = 30 cm; MID = 1.2 cm) (Figure 1).

Discussion

The statistical odds for finding the true score is increased if the average and SEM or MID are used to monitor training load responses, as discussed previously. However, many studies have used the highest jump for analysis [9,12-21,24,25,27], such an approach for monitoring performance questionable in the opinion of these authors. For example, two studies utilizing rugby league players have used the CMJ to monitor 6 weeks of progressive training load and a week taper. CMJ height was used differently in these studies, the study that used the highest jump to monitor performance, did not find significant differences between any phase of the intervention i.e. pre-, post-intervention and taper ($p > 0.05$) [10]. Conversely, when the average CMJ height was used, significant differences were found between pre- and mid- in comparison with the post-intervention [11]. When the highest and average CMJ height were used in the same study, the average CMJ height was still more sensitive according to Hedges' effect size (ESg) results [43]. In addition, Mohr et al. [22] did not find significant decreases in the highest CMJ height [ESg = -0.19 (-0.82 - 0.44)], but found significant decreases to the average CMJ height [ESg = -0.50 (-1.12 - -0.12)] during qualifying games for the UEFA Champions League.

Furthermore, in a recent meta-analysis, investigating the utility of CMJ height it was found that when averaged and highest performance data were pooled into a single analysis, CMJ height was sensitive to supercompensation effects [Overall: ES = 0.37 (0.32 - 0.43), $p = 0.00$;

Table 1: Data from reliability sessions for CMJ performance

| Athlete X | Day 1 | Day 2 | Difference Scores |
|-----------|-------|--------------------|-------------------|
| Rep1 | 28.2 | 30.9 | -2.7 |
| Rep2 | 27.5 | 29.4 | -1.9 |
| Rep3 | 27.5 | 29.8 | -2.3 |
| Rep4 | 30.0 | 30.3 | -0.3 |
| Rep5 | 29.1 | 29.2 | -0.1 |
| Rep6 | 29.3 | 30.9 | -1.6 |
| Rep7 | 28.5 | 29.4 | -0.9 |
| Rep8 | 28.2 | 28.7 | -0.5 |
| | | SD _{diff} | 1.0 |

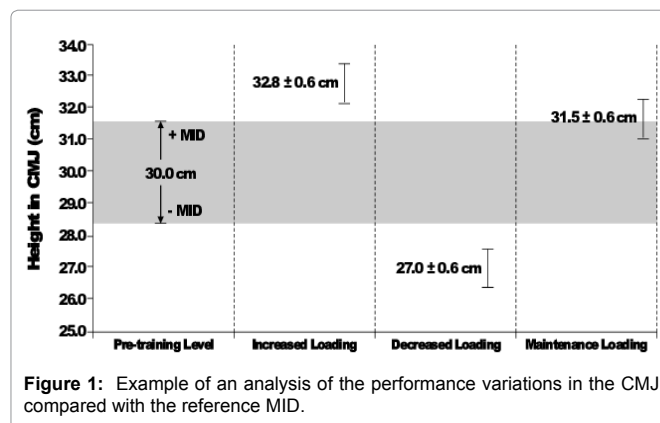


Figure 1: Example of an analysis of the performance variations in the CMJ compared with the reference MID.

I2 = 25.8, p = 0.00]. When partitioned into highest performance and averaged data, the latter was found more sensitive [Highest: ES = 0.33 (0.27 – 0.38), p = 0.00; I2 = 20.0, p = 0.01; Average: ES = 0.74 (0.58 – 0.90), p = 0.00; I2 = 15.8, p = 0.224]. Pooled CMJ height was also found sensitive in determining fatigue [Overall: ES = -0.27 (-0.48 – -0.05), p = 0.01; I2 = 39.8, p = 0.06], however, best performance data was not sensitive [Highest: ES = -0.04 (-0.33 – 0.24), p = 0.76; I2 = 33.5, p = 0.15] whereas, the averaged jump height was sensitive [Average: ES = -0.56 (-0.89 – -0.24), p = 0.00; I2 = 00.0, p = 0.50] [29]. It was concluded that using a single repetition to represent neuromuscular status would seem problematic, the average of 6 [44], 8 [5] and even 12 repetitions [45] have been recommended to best represent CMJ performance and monitor neuromuscular status.

Average CMJ height has been used as a tool for monitoring [3, 4] and for regulating [5,37] training load. Track and field athletes (jumpers and sprinters; [4] middle and long distance runners [3]) have been measured weekly so as in-season performance changes can be tracked e.g. training peaks. Furthermore, the average of CMJ height associated with MID has been applied to regulate plyometric training volume over a 6 week training cycle. CMJ performance was quantified at the beginning of each training session to monitor the individual response to applied loads and thereafter enable load regulation [5]. Additionally, in the team sports athletes (i.e. young futsal players), this approach permitted to monitor and regulate the training load during 4 weeks to induce overreaching and 2 weeks to obtain super compensation in the CMJ performance by tapering. In spite of the regulation group and control group had the same final training load; just the regulation group achieved their pre-determined targets [37]. Implicit in ensuring that the measure is sensitive to change, is that athletes need to be well familiarized with the CMJ [46], as the MID and confidence intervals are calculated from the individual's typical error of measurement.

Practical Applications

The training load can be adjusted individually in high level athletes by researchers and practitioners using the average CMJ height in addition to the MID to monitor neuromuscular status and regulate training load accordingly. The limitations of using highest performance data were detailed and the ease with which MID can be calculated via an excel spreadsheet described. Additionally, to quantify CMJ height requires minimal equipment, and the assessment is easily performed. Furthermore, the practicality of this tool makes it readily applicable throughout the macro cycle, from the pre-season training camp to the in-season competitive phase. Finally, the statistical model described could be applied across a number of other movement patterns (e.g. throwing, punching), and sports (e.g. water polo, combat sports athletes).

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Author Affiliation

Top

¹Laboratory of Biomechanics, University of São Paulo, School of Physical Education and Sport, Brazil

²Sport Performance Research Institute New Zealand, AUT University, New Zealand

³Biomedical and Health Sciences Edith Cowan University, School of Exercise, Australia

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