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Re: A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer: A statistical problem?

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Dear Editors,

We read an interesting approach to monitoring training load in the article titled “A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer” published by Owen and colleagues. Although published in 2017, its recent promotion in practice has sparked discussion within the sport science industry. In this study, a model was proposed to combine training load data from individual training sessions to simplify the reporting process to decision makers. These combined scores are proposed to monitor changes in training load over time and inform the planning of future training. To achieve this, Owen and colleagues (2017) proposed the following equations:

Session Volume Score =

$$\frac{1}{4}\left(\frac{tr\bar{T}D}{\max\limits_{mTD_1},\bar{\ldots},\max\limits_{mTD_n}}+\frac{tr\bar{H}SR}{\max\limits_{mHSR_1},\bar{\ldots},\max\limits_{mHSR_n}}+\frac{tr\bar{S}D}{\max\limits_{mSD_1},\bar{\ldots},\max\limits_{mSD_n}}+\frac{tr\,(acc\bar{+}dec)}{\max\limits_{m(acc+dec)_1},\bar{\ldots},\max\limits_{m(acc+dec)_n}}\right)100$$

Session Intensity Score =

$$\frac{1}{4}\left(\frac{tr\bar{T}D/t}{\max\limits_{mTD_1/t},\bar{\ldots},\max\limits_{mTD_n/t}}+\frac{tr\bar{H}SR/t}{\max\limits_{mHSR_1/t},\bar{\ldots},\max\limits_{mHSR_n/t}}+\frac{tr\bar{S}D/t}{\max\limits_{mSD_1/t},\bar{\ldots},\max\limits_{mSD_n/t}}+\frac{tr\,(acc\bar{+}dec)/t}{\max\limits_{m(acc+dec)_1/t},\bar{\ldots},\max\limits_{m(acc+dec)_n/t}}\right)100$$

Where, tr = training. TD = total distance. HSR = high speed running. SD = sprint distance. acc = acceleration. dec = deceleration. max = maximum. m = match. $_{1},\ldots,n$ = each participants data. *t* = time.

Firstly, the team average in each variable from training is represented as a percentage of the average maximal match load from all players in the squad. This approach was presumably taken to normalise the variables to overcome their different scales (e.g. distance = 7000 m, high-speed running = 600 m). These percentages are averaged and then multiplied by 100 to present a single combined percentage score for the training session.

We share the authors' view that refining how data are communicated to stakeholders is an important and contemporary issue facing applied sports scientists (Weaving et al. 2017; Weaving et al., 2019). This is due to the array of measures that are used to represent both the internal and external training load constructs (McLaren et al., 2018) and the variety of training modalities that players complete (Weaving et al., 2014). In addition, evidence detailing relationships between different training load measurements and different training responses suggest the need to consider multiple training load measures to inform the overall training process (Akubat et al., 2012; Oxendale et al., 2016; Fitzpatrick et al., 2018). We applaud the efforts of the authors in their attempts to contextualise multiple training load variables and work closer with coaches, however; we believe their 'multi-modal mechanical approach' in its current form has statistical limitations that need to be considered when evaluating its validity for research and practice.

Notwithstanding the potential issues of scaling training load values as a percentage of maximal match load (Lolli et al., 2019), a statistical issue arises when multiple measures are averaged together. This is because there is no consideration for the amount of covariance between the measures as each variable is treated as entirely independent. When meta-analysed, numerous training load measures possessed large relationships with each other (i.e. demonstrate covariance) (McLaren et al., 2018). However, the strength varies substantially between training modalities (e.g.

conditioning vs. technical-tactical training) and training load measures (Weaving et al., 2014; Weaving et al., 2017; McLaren et al., 2018). For example, during mixed technical-tactical and conditioning based training, there was a *very large* (r = 0.82) relationship between session rating of perceived exertion training load (sRPE-TL) and total distance (McLaren et al., 2018). However, this decreased for technical-tactical (r = 0.52) and neuromuscular-training (r = 0.4). Relationships have also been observed between different external load measures (e.g. total distance vs PlayerLoad™) (Weaving et al., 2014; Weaving et al., 2018).

Consequently, collinearity is likely to be present for all combinations of training load measures used in the multi-modal mechanical approach and potentially more problematic for different modalities of training. By not accounting for the covariance between measures, the 'multi-modal mechanical' score, in its current form, will be biased towards the measures that have the strongest relationship with each other, even though they provide similar information over time. Conversely, the measures providing different information (i.e. less covariance to others) will provide less of a contribution to the combined score. This contradicts the conceptual aim of analysing multiple measures to capture different aspects of the training load construct. Therefore, it is questionable whether the authors have achieved a valid 'multi-modal mechanical approach' to quantifying training volume and intensity.

To combine data into a reduced number of variables while also accounting for the collinearity between them, techniques, such as principal component analysis (PCA) (Weaving et al., 2019), multiple factor analysis (MFA) (Abdi, Williams and Valentine, 2013) or multidimensional scaling (MDS) can be used (Woods et al., 2018).

Generally, such techniques take the original variables, combine the information (or variance) and redescribe them by constructing ‘new’ variables – often termed principal components (PCA), factors (MFA) or dimensions (MDS) dependent on the technique.

Each ‘new’ variable is constructed by ‘weighting’ the original variables. Each are weighted in a way that 1.) maximises covariance of the original variables whilst also 2.) separating uncorrelated variance between the ‘new variables’. By doing so, the covariance between the measures has been considered whilst also ensuring each ‘new’ variable reflects distinctly different information provided by the original variables. The original variables can then be multiplied by these weightings to produce combined scores that can be used in practice. By using the first two ‘new variables’, which generally capture the majority of the total variance, simpler visualisations and reporting of multiple training load variables can be conducted similar to the concept proposed by Owen and colleagues (Weaving et al. 2019). This can then be used to evaluate differences within- and between-players and matches.

While these methods are more difficult to conduct than the multi-modal mechanical model equations, there are freely available sources that demonstrate applications of such techniques within sport science research (Woods et al., 2018; Weaving et al., 2019) and can be conducted on different platforms (e.g. R Studio, SPSS). More philosophically, it is important to satisfy the ‘working fast’ environment of the applied sport scientist (Coutts, 2017) and ensure simplicity. However, we must equally consider that the resources spent on athlete monitoring (e.g. microtechnology) necessitate that we, (as applied sports scientists), strive towards analyses that capture the complexity of the training process while balancing the need to communicate data to stakeholders involved in decision making.

As part of this process, and irrespective of the analysis method chosen, it is vitally important that practitioners first consider the conceptual reasoning for the inclusion of any measure into a combined score and the quality of evidence regarding it's individual validity and reliability aligning to a conceptual framework. Once this has been conducted, practitioners should evaluate the validity of these combined variables and the extent that they provide better information on the important outcomes of the training process (e.g. training adaptation) that such measures attempt to inform. We welcome new approaches that advance the monitoring and interpretation of training load data but advise against sport scientists using the multi-modal mechanical approach proposed by Owen and colleagues (2017) in its current form.

Disclosure of Interest

The authors report no conflict of interest.

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