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INVITED COMMENTARY

Internal and External Training Load: 15 Years On

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Exercise is a stressor that induces various psychophysiological responses, which mediate cellular adaptations in many organ systems. To maximize this adaptive response, coaches and scientists need to control the stress applied to the athlete at the individual level. To achieve this, precise control and manipulation of the training load are required. In 2003, the authors introduced a theoretical framework to define and conceptualize the measurable constructs of the training process. They described training load as having 2 measurable components: internal and external load. The aim of this commentary is to extend, clarify, and refine both the theoretical framework and the definitions of internal and external training load to avoid misinterpretation of this concept.

Keywords: workload, exercise training, stimulus, stressor, psychobiological response

The concepts of internal and external training load were first presented at the Eighth Annual Congress of the European College of Sport Science in Salzburg, Austria (2003)[1] at an invited session and symposium organized by Tom Reilly. The content of this presentation was included in 2 follow-up papers, which first described the taxonomy of the training stimulus.[2,3] Although these concepts were initially proposed in the context of team sports, the terms internal and external training load are now used more generally in both the research and practice.[4–7] In the original article, the concepts of internal and external load were introduced, but we did not address them in depth. Therefore, the intention of this commentary is to extend, clarify, and refine both the theoretical framework and the definitions of internal and external training load to also avoid misapplication or misinterpretation of these concepts as they were originally proposed.

Theoretical Framework: The Training Process

Athletic or sport training has been defined as the process of systematically performing exercises to improve physical abilities and to acquire specific sport skills.[8] When delivered appropriately, exercises induce a functional adaptive response. It is these functional adaptations that underpin changes in various training outcomes such as physical performance, injury resistance, or health. The exercise bout induces a psychophysiological response, and it is this response (rather than the exercise task itself) that provides the stimulus for adaptation.[9] Potentially, any strategy inducing the same response would have a similar effect (eg, pharmacological interventions).[10] The athlete's response to the stimulus and the stimulus itself is specific to the nature, intensity, and duration of the exercise task.[8] A single exercise bout can generate a stimulus that elicits a transient acute adaptive response while the systematic repetition of this stimulus and the associated response are necessary to elicit chronic adaptations. This training stimulus should also to be applied at sufficient time periods and be of appropriate magnitude to prevent decay of these adaptations prior to competition. According to the principle of reversibility, if the stimulus discontinues, previous adaptations revert and performance declines.[11] To obtain specific performance adaptations, training needs to target the systems that determine performance (Figure 1).

Training Load: Internal and External Load

The training load in the context of athletic training has been described as the input variable that is manipulated to elicit the desired training response.[12] Training load can be described as being either external and/or internal,[2,3] depending if we are referring to measurable aspects occurring internally or externally to the athlete. The organization, quality, and quantity of exercise (training plan) determine the external load, which is defined as the physical work prescribed in the training plan.[2,3,12] Accordingly, measures of external load are specific to the nature of training undertaken. For example, the external load in resistance training is usually considered the load (external resistance) lifted; however, it may also be expressed as work completed or the velocity generated during lifting.[13] Similarly, in team sports, external load can be described by measures of total distance covered (or in specific speed bands), accelerations, or metabolic power (as examples).[14] Despite its name (ie, it infers metabolism, which is internal to the athlete), the latter is mathematically derived from the speed–time profile and therefore remains an external load indicator. Irrespective of how it is quantified, coaches prescribe training according to external load to elicit the desired psychophysiological response. It is this response that corresponds to the internal training load. Accordingly, measures of internal load can be indicators reflecting the actual psychophysiological response that the body initiates to cope with the requirements elicited by the external load. Therefore, the concept of internal load incorporates all the psychophysiological responses occurring during the execution of the exercise (single or sequence) prescribed by the coach. According to our definitions, the concepts of external and internal load do not have a single or gold standard measure, but rather these may be quantified by a myriad of variables, which describe the external load or the internal response during the exercise. In addition, the validity of a measure

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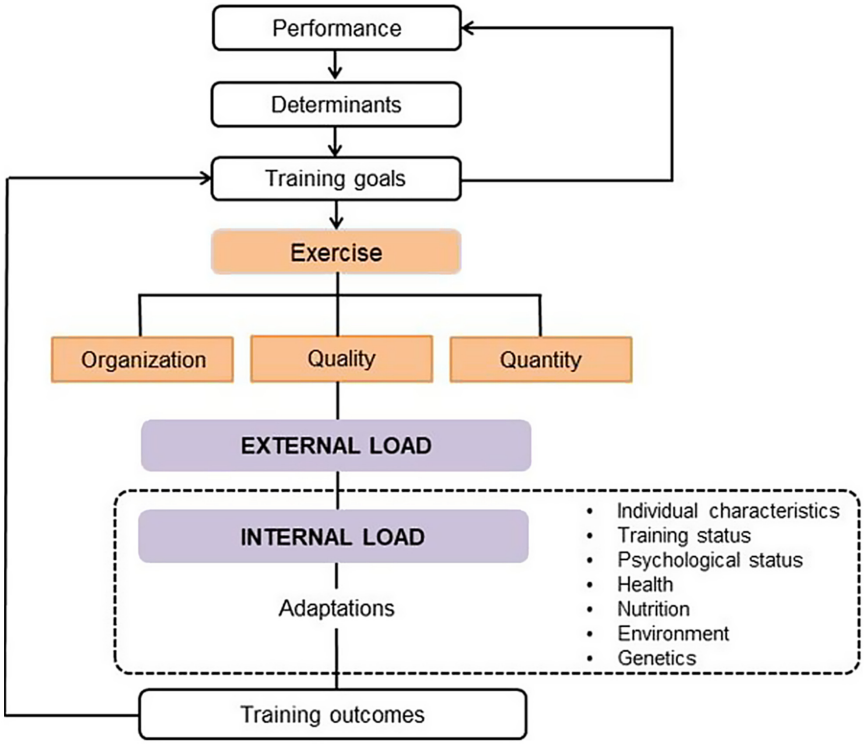

Figure 1 — Theoretical framework of the training process.

of a load indicator depends upon the context. For example, heart rate is a valid measure of internal load for endurance training but not for resistance training. Moreover, even within the same context, a single load measure may not have the same level of validity (eg, heart rate is a less valid indicator of internal load in short duration, intermittent high-intensity efforts compared with long distance or interval training).

Internal Over External Load

As the internal training load determines the training outcome, we recommend that this can be used as primary measure when monitoring athletes. This is because the internal load experienced from a specific external load may vary depending on specific contextual factors either between or within athletes. For example, specific modifiable and nonmodifiable factors such as training status, nutrition, health, psychological status, and genetics may result in individual athletes experiencing a different internal load (and individual differences in adaptive processes[15]) when provided same external load (Figure 1).[16–18] As some of these characteristics are not fixed, the internal load experienced by a specific athlete for a given external load may also change when these factors are modified (ie, changes in their training status, health, etc). In addition, the stress response (ie, internal load) can be influenced by other stressors (eg, hot conditions during training) affecting the psychophysiological response to exercise.

Therefore, from a practical point of view, it is difficult to precisely estimate the individual's actual internal load prior to exercise. This is especially the case during exercise bouts that are characterized by spontaneous activities and/or those that are influenced by self-pacing and sparing behaviors (eg, small-sided games, match play, or sparring in combat sports). Due to these factors, we recommend that internal load can be assessed directly so that we can be sure that the intended psychophysiological response was induced as planned.

The recent development of more sophisticated (micro)technology now allows for increasingly detailed information about external load.[19] For example, with the use of GPS (global positioning systems), accelerometers, and gyroscopes, it is now relatively simple to quantify accelerations, decelerations, speed, and power during exercise. However, as a result of the increased availability of these devices, the attention of coaches and scientists appears to have shifted to examining the external load rather than the actual psychophysiological response (ie, internal load). Caution should be taken in shifting this attention if we are monitoring athletes. In this case, it is the internal load rather than the external load, which ultimately determines the functional outcome of training and therefore should be monitored. However, the advantage of having greater information on the external load is that this may allow for more precise prescription of external load.

External Over Internal Load

In practice, it is not always possible to measure the internal load as there are situations where there may not be a readily available valid indicator of the internal load. For example, single and repeated sprint interval training induces greater neuromuscular responses (internal load) compared other forms of high-intensity training that involve longer duration bouts completed at lower speeds.[20] However, at present, there are no established valid indicators of neuromuscular involvement that are available to be used during real training conditions. By contrast, there are other indicators of external load such as velocity or time (to complete the sprints) that are easily measurable and these are typically applied. It is

commonly assumed that there is a higher involvement of neuromuscular components with increasing running speed.[21] Similarly, external load indicators such as weight lifted, work, and time under tension are commonly used in resistance-based training. However, also for strength training methods, internal load measures based on perceived exertion have been proposed.[13] Practitioners often implicitly estimate internal load based on these measures of external load; however, as explained previously, this approach is conceptually limited as it cannot be assumed a direct correspondence between external load and internal response.

Integrating Internal and External Load

Despite the increased availability of external load assessment tools, we caution against the exclusive use of this load measure for monitoring athletes as it has conceptual limitations. For example, it is difficult to make accurate interindividual comparisons of how athletes are responding to (or coping with) training (eg, low responders vs high responders). Indeed, by definition, a low responder is an athlete who has a lower response to the same internal load, which stipulates that internal load measures are required for such evaluations. To this regard, also the use of an appropriate internal load indicator is crucial. For example, it is well known that the percentage of maximal oxygen uptake (VO_2max) can correspond to different percentages of the lactate thresholds.[22] Therefore, athletes exercising at the same percentage of the VO_2max can have different internal load responses (lactate thresholds) explaining apparently different training-induced adaptations (responder vs nonresponder when using the percentage of VO_2max as internal load indicator).[23] In addition, from a conceptual point of view, there are additional advantages in integrating internal and external load measures for monitoring training. For example, the uncoupling between internal and external load may be used to identify how an athlete is coping with their training program. Specifically, athletes who exhibit a lower internal load to standardized external load completed in similar conditions, would be assumed to reflect increased fitness. By contrast, when the internal load is increased in this situation, the athlete may be losing fitness or suffering from fatigue. Moreover, the combination of psychological and physiological measures of internal training load may suggest the kind of fatigue the athlete is suffering from. Specifically, muscle fatigue increases both heart rate and rating of perceived exertion,[24] whereas mental fatigue increases only rating of perceived exertion.[25] This knowledge may help to choose the most appropriate intervention to reduce fatigue, for example, a reduction in muscle-damaging exercise or better sleep hygiene.

Clarifying Internal-Load Indicators

As previously mentioned, internal load is defined as the psychophysiological response during exercise. There is a common misconception that measures such as heart rate recovery or heart rate variability collected after the exercise (immediately after or in the following morning) are indicators of internal load. However, according to the definition, these measures cannot be considered internal load indicators as these are responses occurring after and not during the exercise. We suggest that a postexercise response can be used as an indirect (surrogate) measure of the internal load when there is a strong association between these 2 variables (ie, internal load and the surrogate). But even in this situation, this measure is not strictly speaking a measure of the internal load but a measure of the postexercise response to the internal load. Similarly, other common athlete monitoring measures such as the hormonal response after exercise, jump tests used to assess neuromuscular fatigue or self-reports about postexercise symptoms (eg, fatigue and muscle soreness) should not be considered as measures of internal load. As a rule of thumb, an indicator of the internal training load is any indicator that can be used to prescribe exercise intensity.

Practical Applications and Conclusions

After 15 years since the conceptual model was first presented, the concepts of internal and external load are now widespread and common in both research and practice. In this commentary, we have clarified the definitions of internal and external load and also explained the relevance of these constructs within the training process. Furthermore, we have highlighted the importance of using internal load, especially when monitoring athletes and discussed the limitations of the exclusive use of external load for this purpose. Finally, we presented the advantages (conceptually) of contextualizing internal and external load in understanding the training process. As this model can be applied to understand the link between training and the individual adaptive response, it is suitable as the theoretical framework for developing athlete monitoring systems. When these systems are implemented effectively, they can assist coaches and scientists to better control and optimize the training process.

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