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INVITED COMMENTARY

Training-Load Management Ambiguities and Weak Logic: Creating Potential Consequences in Sport Training and Performance

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Background: The optimization of athlete training load is not a new concept; however in recent years, the concept of "load management" is one of the most widely studied and divisive topics in sports science and medicine. ***Purpose:*** Discuss the challenges faced by sports when utilizing training load monitoring and management, with a specific focus on the use of data to inform load management guidelines and policies/mandates, their consequences, and how we move this field forward. ***Challenges:*** While guidelines can theoretically help protect athletes, overzealous and overcautious guidelines may restrict an athlete's preparedness, negatively influence performance, and increase injury risk. Poor methods, wrong interpretation of study findings, and faulty logic do not allow for systematic scientific evaluations to inform guidelines. ***Practical Solutions:*** Guidelines and mandates should be developed through a systematic research process with stronger research designs and clear research questions. Collaborating with statistical and epidemiological experts is essential. Implementing open science principles and sharing all sports training load data increase transparency and allow for more rapid and valid advancements in knowledge. Practitioners should incorporate multiple data streams and consider individual athlete responses, rather than applying broad guidelines based on average data. ***Conclusion:*** Many current training load guidelines and mandates in sports come from good intentions; however, they are arbitrary without sound knowledge of the underlying scientific principles or methods. Common sense guidelines are helpful when there is sparse literature, but they should be careful to avoid arbitrarily choosing findings from weak research. Without precise scientific inquiries, implementing training load interventions or guidelines can have negative implications.

Keywords: accelerometer, causality, prediction, open science

Load management has been defined by the International Olympic Committee as "the appropriate prescription, monitoring and adjustment of external and internal [training] loads,"[1] which summarizes the traditional concepts of physical training, periodization, and programming, where the aim is to optimize performance (and minimize the risk of injury).[2] Individualized strategies for load management have been integrated across sports, focusing on the multiple inputs and outputs to monitor responses, including heart rate, self-reported outcome, neuromuscular, cognitive, and sport performance.[3] However, in recent years, the concept of "load management" and more specifically, the relationship between training load and injuries has become one of the most widely studied areas of sports medicine,[4] generating debate in both research and public domain.[5] From everyday members of the public to the athletes pushing the boundaries of human performance, the explosion of health technologies and data availability has catapulted this topic into the mainstream, for both the right and wrong reasons. In this editorial, we discuss the challenges faced by sports when utilizing training load monitoring and management, with a specific focus on the use of data to inform load management guidelines and policies/mandates, their consequences, and how we move this field forward.

Can We Really Fault the Workman for Blaming His Tools?

Training load, that is, the amount of physical training, is a desirable target for intervention in many cases, given the apparent ease with which it can be quantified, monitored, and modified. Within any one of these processes however, a risk–benefit (ie, injury performance) analysis occurs and a decision must be made whether an athlete can continue their training/competition as scheduled, modify the training/competition, or stop altogether. Adding layers of complexity to these everyday decisions are the countless contextual factors that members of the multidisciplinary team must account for, including player-level factors (eg, physical, psychological, and demographic); environmental factors (eg, weather, surface type, equipment); and team-level factors (eg, match related).[3] This complexity is not unique to sport and exists in most other fields (eg, medicine, sociology, economics).

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Another challenge in sport relates to the validity and effectiveness of currently available load monitoring tools to support decision making for injury prevention. Indeed, validity is not a generic concept and depends on the context. For example, one of the most widely used tools for monitoring athletes are inertial sensor units, which have embedded in them global (or local for indoor sport) positioning systems, accelerometers, gyroscopes, and magnetometers.[6] These units are commonly worn on the upper extremity (between the scapulae) and can provide valid time motion data in some contexts that can be used to quantify load and inform the planning of future training sessions. Unfortunately, while these units are easy to use and provide a wealth of metrics, their causal relationship with injury and/or performance has not been adequately studied and their validity in some contexts is questionable on theoretical grounds. First, their ability to quantify whole-body accelerations has been questioned due to the complex multisegmental movement of the body in common field and court tasks.[6] Second, trunk-worn accelerometry has a poor relationship with actual ground reaction forces occurring in the lower extremity during running tasks. Ultimately, injuries occur because the applied load exceeds the load capacity at a specific location, not on the body as a whole. These metrics, which are usually proxy estimations rather than exact measurements, do not currently provide the information necessary to determine load at this level of detail.[6] As such, these technologies and metrics must be considered in the context of their limitations.

Guidelines Versus Mandates: Examples From Sport

Guidelines and policies related to athletes' exposure to sport are widespread from the grassroots to the elite.[7,8] Youth sports have long held many loading guidelines designed to nurture athletic development and ensure safe play, such as those related to age-grade law variations in rugby,[7] and limiting pitch counts in baseball.[8] Guidelines or mandates targeting professional sports often receive the most media coverage and demand the greatest resources for implementation. For example, American Football introduced contact limits in training.[9] Beyond collision sports, other policies have been adopted, including the National Basketball Association's load management strategies.[5]

Guidelines Versus Mandates: Why the Language Matters

When implementing load management strategies, the difference between guidelines and mandates/rule changes is a key distinction. Mandates or rules are often more effective than single-player load management recommendations, given their ability to direct whole populations and limit the exposure to risks. They are often used to target specific risky actions, for example, full contact (and as a result, head contact) in training. Furthermore, they frequently act in a precautionary way when dealing with phenomena which are yet to be fully understood. Guidelines on the other hand, often do not require mandatory action and are supposed to provide stakeholders with the most recent general principles to follow for that sport, understanding that exceptions exist based on context. Irrespective of being defined as rules or guidelines, these preventative approaches are often speculative and based on common sense, rather than rigorous scientific studies given the limitations of the research itself (sometimes unrecognized or unacknowledged).

Challenges of Training-Load Mandates: Negative Consequences

Overcautious Guidelines Concerning Training Load

Overcautious training load guidelines or the uncertainty and fear they can generate may hinder an athlete's ability to develop robustness and physical preparedness for sport.[10] Self-limiting guidelines do not account for periods where the athlete needs to prepare for maximal performance. In these instances, athlete training must be near their limits (ie, designed overreaching periods) to effectively improve performance. While cautiously decreasing training load limits the amount of time at exposure for injury, such self-limiting guidelines, imposed rules, or mandates could reduce the ability of players to develop or maintain the physical qualities necessary for high performance.[11] While guidelines can help reduce training and performance "abuses," overzealous and overcautious guidelines may compromise athlete preparedness, impeding athlete development, and potentially increasing athlete injury risk.

Training-Load Faulty Assumptions

The majority of sports science literature has studied the statistical association of various training load metrics and injury outcomes without incorporating causal inference methods. These associations are then used as targets for athlete interventions, as if the authors inferred all relationships were causal. However, typical statistical associations in publications only consider the strength and direction of a statistical relationship between the factor and outcome, and not how another variable (or variables) impacts the relationship.[12] Only evidence of causal relationships should inform and impact medical interventions, and cause–effect relationships should only be inferred when appropriate methods are used.[13]

To provide an example, the original acute:chronic workload ratio research was designed as an injury risk prediction model and as a "risk factor."[14] Risk factor/prediction studies not adopting causal frameworks and methods (the majority) should be considered exploratory evidence for future interventions, as they include both causal and noncausal (eg, confounding, random noise) predictors of the outcome.[15] Inferring causality from such studies is inappropriate and potentially harmful through unintended consequences, such as wasting time on interventions that have little or no impact on the outcome or, worse yet, increasing injury risk through an unanticipated different mechanism altogether.[11] For example, a randomized controlled trial of 34 elite youth football teams (n = 394), using software that identified when the acute:chronic workload ratio exceeded guidance, showed no reduction in injury and health problems.[16] In this specific context, one might conclude the intervention was ineffective. However, the methods used could not assess the causal effect of load management because data were not collected on the planned activity, or the activity done by either group. Therefore, we do not know how often, if ever, the planned activity would have exceeded guidance, or when the guidance was ignored by the coach. Hence, this study can only ascertain if the program was effective at the cluster level in reducing injuries. When a valid model is available, the effects of its implementation should be examined (ie, impact studies) to ensure a positive impact, to exclude the possibility of unanticipated detrimental effects.[17]

Training-Load Methodological and Logical Concerns

There is a perception in some sport circles that decreasing the training load, especially games or matches, reduces injury risk. Reducing overall physical load by avoiding practice or play, reduces the time at risk, which decreases the time of athlete exposure.[18] This may be pertinent in contact sports where the goal can be to reduce the exposure to risky activities. However, this training load strategy may or may not change an athlete's risk of sustaining an injury per minute of sport exposure (ie, injury rate),[19] which should be the goal of load management as a preventive intervention. Furthermore, reducing physical activity and availability of key influential players may have negative effects on team performance and/or media coverage, with important economic implications.

All people making decisions must decide the amount of risk that is acceptable given the potential benefits. Currently, there is no consensus on what is an acceptable injury risk in relation to training load within the sport community. In fact, acceptable sport injury risk will vary based on many factors, including the sport, environment, context, and time remaining in a match or season.[20] In a hypothetical example, an athlete suffers a grade 2 medial cruciate ligament knee sprain. A young amateur athlete at the beginning of the season might be willing to accept less risk compared to a professional athlete during the playoffs. Such decisions will be unique to each club, situation, and their context, making general recommendations challenging given that the risk tolerance is more fluid than a fixed decision ("go/no-go") threshold.

Although some argue that economic concerns should be secondary to athlete health concerns, employment and performance are related to self-identity and mental health.[21] Risk cost analyses have not been properly studied to evaluate how different injury risk thresholds affect individual athletes and clubs at the monetary level, which will impact risk tolerance.[20] Current discussions in the National Basketball Association indicate that fans pay a large amount of money to attend games to see their favorite players compete. However, if the player is resting on a given night, in the name of "load management," the probability of winning is affected. Fans might simultaneously get frustrated with the product on the court and potentially attend fewer games.[5] Furthermore, they may also become less enthusiastic about athletes who sit out, which can result in decreased salaries for these athletes, which in turn might result in an athlete willing to accept greater risk.[22] Because the economic impact of such an outcome is vital to the success of the athlete and the club, involving appropriate knowledge users is imperative. This would constitute a 2-part knowledge user inquiry, integrating community members, athletes, and coaches' knowledge user sessions, followed by presenting these key themes to club presidents, general managers, and governing bodies to create more precise risk cost analyses.

Practical Solutions

Emphasizing High-Quality Studies to Support Training-Load Mandates

We require improved research designs that address clear research questions to inform and support training load guidelines and mandates. For example, if a prediction model based on training load data is developed, sound methods should be followed.[15] The attention is on its prediction performance and not on the predictors themselves. Once it is internally and externally validated, its actual impact, once implemented, should also be examined.[15] If training load is investigated as a causal risk factor, causal inference frameworks and associated methods should be used before suggesting it as a target for interventions. Guidelines and mandates should be developed through a systematic process, supported by available research.[13] As stated previously, many training load research studies use faulty assumptions and have important methodological and logical concerns. These issues impair the ability to evaluate both (1) causal links between load and injury[13] and (2) decision analyses that weigh the cost–benefit of different load scenarios.[3] Perhaps the most important path toward improving study design and methodological quality is to collaborate with knowledgeable, experienced statisticians and epidemiologists in the specific area of inquiry, which can aid in removing barriers to solving these important questions. These collaborations are expected to help clarify the specific injury outcome (due to the multifactorial nature of injury), provide clarity on the causal assumptions (including the clarification of the use of proxies vs direct measures), and identify sufficient sample sizes that improve the scientific investigation. Without clear and sound evidence, guidelines and mandates will not have the requisite knowledge to inform training and competition load management strategies. At best, these recommendations should be interpreted as "current opinions" that will change in the future as evidence develops, regardless of whether they are reached by consensus or represent the perspective of a sports governing body.

Applying Open-Science Practices

While not a novel concept, current sport research is limited in using open science principles.[23] High-quality research is related to its transparency, openness, and reproducibility. Implementing open science principles can improve scientific investigations at a faster rate through public discussion compared to closed scientific practices.[24] Software code and registered reports should be freely shared and deposited in an open-access repository. This would allow other sports scientists and researchers to review and potentially improve the proposed methods and software code. While freely accessible data can have limitations within a sporting environment, data or synthetic data can be shared to at least assess reproducibility.[24]

Applying a Critical Mindset in Applied Practice

Monitoring the training load can help facilitate the ongoing optimization of the training process through athlete and practitioner awareness, rather than rigidly following or creating guidelines and mandates. When presenting decisions or interventions pertaining to the design and adjustment of training load, practitioners must remain cognizant of the limitations inherent in their data capture methodologies.[6] Load data should be combined with training response data streams (eg, neuromuscular, cardiovascular, biochemical, and/or perceptual data collection), and individualized to a specific player. Understanding individual athlete response to training load, rather than relying on training load guidelines/mandates based on an "average player," may provide more precise data to improve athlete training and performance.

Conclusion

The current training-load guidelines and mandates in sport come from good intentions but are often created without adequate knowledge of the underlying scientific principles or methods. Without precise scientific inquiries and accounting for the unique risk and cost–benefit of different scenarios or player capacities, applying training-load interventions or guidelines based on an "average player" can have unintended consequences and implications for injury, performance, and athlete development.

References

1. Soligard T, Schwellnus M, Alonso J-M, et al. How much is too much? (part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med*. 2016;50(17): 1030–1041. doi:10.1136/bjsports-2016-096581
2. Stone MH, Hornsby WG, Haff GG, et al. Periodization and block periodization in sports: emphasis on strength-power training—a provocative and challenging narrative. *J Strength Cond Res*. 2021;35(8):2351–2371. PubMed ID: 34132223 doi:10.1519/JSC.0000000000004050
3. West SW, Clubb J, Torres-Ronda L, et al. More than a metric: how training load is used in elite sport for athlete management. *Int J Sports Med*. 2021;42(04):300–306. doi:10.1055/a-1268-8791
4. Drew MK, Finch CF. The relationship between training load and injury, illness and soreness: a systematic and literature review. *Sports Med*. 2016;46(6):861–883. doi:10.1007/s40279-015-0459-8
5. Aschburner S. Adam Silver discusses new policy as load management goes "too far." Accessed February 4, 2024. https://www.nba.com/news/adam-silver-load-management-bog-news-conference-2023
6. Nedergaard NJ, Robinson MA, Eusterwiemann E, Drust B, Lisboa PJ, Vanrenterghem J. The relationship between whole-body external loading and body-worn accelerometry during team-sport movements. *Int J Sports Physiol Perform*. 2017;12(1):18–26. doi:10.1123/ijspp.2015-0712
7. Canada R. Age grade law variations for community Rugby. 2023. https://rugby.ca/uploads/Community/Age_Grade_Law_Variations_for_Community_Rugby_2022_Eng_v3.pdf
8. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *Am J Sports Med*. 2002;30(4): 463–468. doi:10.1177/03635465020300040201
9. Broglio SP, Williams RM, O'Connor KL, Goldstick J. Football players' head-impact exposure after limiting of full-contact practices. *J Athl Train*. 2016;51(7):511–518. PubMed ID: 27333460 doi:10.4085/1062-6050-51.7.04
10. Gabbett TJ. The training—injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med*. 2016;50(5): 273–280. doi:10.1136/bjsports-2015-095788
11. Impellizzeri FM, Menaspà P, Coutts AJ, Kalkhoven J, Menaspà MJ. Training load and its role in injury prevention, part I: back to the future. *J Athl Train*. 2020;55(9):885–892. PubMed ID: 32991701 doi:10.4085/1062-6050-500-19
12. Altman DG, Lyman GH. Methodological challenges in the evaluation of prognostic factors in breast cancer. *Breast Cancer Res Treat*. 1998;52(1–3):289–303. PubMed ID: 10066088 doi:10.1023/A:1006193704132
13. Losciale JM, Bullock GS, Collins GS, et al. Description, prediction, and causation in sport and exercise medicine research: resolving the confusion to improve research quality and patient outcomes. *J Orthop Sports Phys Ther*. 2023;53(7):381–387. doi:10.2519/jospt.2023.11773
14. Wang C, Vargas JT, Stokes T, Steele R, Shrier I. Analyzing activity and injury: lessons learned from the acute: chronic workload ratio. *Sports Med*. 2020;50(7):1243–1254. doi:10.1007/s40279-020-01280-1
15. Bullock GS, Hughes T, Sergeant JC, Callaghan MJ, Riley RD, Collins GS. Clinical prediction models in sports medicine: a guide for clinicians and researchers. *J Orthop Sports Phys Ther*. 2021; 51(10):517–525. doi:10.2519/jospt.2021.10697
16. Dalen-Lorentsen T, Bjørneboe J, Clarsen B, Vagle M, Fagerland MW, Andersen TE. Does load management using the acute: chronic workload ratio prevent health problems? A cluster randomised trial of 482 elite youth footballers of both sexes. *Br J Sports Med*. 2021; 55(2):108–114. doi:10.1136/bjsports-2020-103003
17. Reilly BM, Evans AT. Translating clinical research into clinical practice: impact of using prediction rules to make decisions. *Ann Intern Med*. 2006;144(3):201–209. PubMed ID: 16461965 doi:10.7326/0003-4819-144-3-200602070-00009
18. Impellizzeri FM, Shrier I, McLaren SJ, et al. Understanding training load as exposure and dose. *Sports Med*. 2023;53(9):1667–1679. doi:10.1007/s40279-023-01833-0
19. Malilay J, Henderson A, McGeehin M, Flanders WD. Estimating health risks from natural hazards using risk assessment and epidemiology. *Risk Anal*. 1997;17(3):353–358. PubMed ID: 9232018 doi:10.1111/j.1539-6924.1997.tb00873.x
20. Shrier I. Strategic Assessment of Risk and Risk Tolerance (StARRT) framework for return-to-play decision-making. *Br J Sports Med*. 2015;49(20):1311–1315.
21. Lamont-Mills A, Christensen SA. Athletic identity and its relationship to sport participation levels. *J Sci Med Sport*. 2006;9(6):472–478. PubMed ID: 16765643 doi:10.1016/j.jsams.2006.04.004
22. Cisyk J, Courty P. An economic approach to sports injury policies. *J Sports Econ*. 2023;25(3):388–419. doi:10.1177/15270025231222635
23. Bullock GS, Ward P, Impellizzeri FM, et al. Up front and open, shrouded in secrecy, or somewhere in between? A meta research systematic review of open science practices in sport medicine research. *J Orthop Sports Med*. 2023;53(12):735–747.
24. Bullock GS, Ward P, Impellizzeri FM, et al. The trade secret taboo: open science methods are required to improve prediction models in sports medicine and performance. *Sports Med*. 2023;53(10): 1841–1849. doi:10.1007/s40279-023-01849-6