Journal Pre-proof


# Misuse of the term 'load' in sport and exercise science

Craig A. Staunton, Grant Abt, Dan Weaving, Daniel W.T. Wundersitz

PII: S1440-2440(21)00212-7

DOI: https://doi.org/10.1016/j.jsams.2021.08.013

Reference: JSAMS 2576

To appear in: *Journal of Science and Medicine in Sport*

Received date: 10 May 2021

Revised date: 10 August 2021

Accepted date: 12 August 2021

Please cite this article as: C.A. Staunton, G. Abt, D. Weaving, et al., Misuse of the term 'load' in sport and exercise science, *Journal of Science and Medicine in Sport* (2021), https://doi.org/10.1016/j.jsams.2021.08.013

# Misuse of the term ‘load’ in sport and exercise science

Craig A. Staunton[a*], Grant Abt[b], Dan Weaving[c,d] and Daniel WT. Wundersitz[e]

[a] *Swedish Winter Sports Research Centre, Department of Health Sciences, Mid Sweden University, Östersund, Sweden.*

[b] *Department of Sport, Health, and Exercise Science, The University of Hull, Kingston upon Hull, United Kingdom.*

[c] *Carnegie Applied Rugby Research (CARR) Centre, Carnegie School of Sport, Leeds Beckett, Leeds, United Kingdom.*

[d] *Leeds Rhinos Rugby League Club, Leeds, United Kingdom.*

[e] *Holsworth Research Initiative, La Trobe Rural Health School, La Trobe University, Bendigo, Australia.*

***** *Correspondence:*

**Corresponding Author:** Dr Craig Staunton

Swedish Winter Sports Research Centre

Kunskapensväg 8, Hus D

831 25 Östersund, Sweden

**Email:** craig.staunton@miun.se

**Tel:** +46 073-822 13 05

**Word Count: 3698**

**Abstract Word Count:** 159

**Number of Tables:** 1

**Number of Figures:** 1

**Misuse of the term ‘load’ in sport and exercise science**

## ABSTRACT

Despite the International System of Units (SI), as well as several publications guiding researchers on correct use of terminology, there continues to be widespread misuse of mechanical terms such as ‘work’ in sport and exercise science. A growing concern is the misuse of the term ‘load’. Terms such as ‘training load’ and ‘PlayerLoad’ are popular in sport and exercise science vernacular. However, a ‘load’ is a mechanical variable which, when used appropriately, describes a force and therefore should be accompanied with the SI-derived unit of the newton (N). It is tempting to accept popular terms and nomenclature as scientific. However, scientists are obliged to abide by the SI and must pay close attention to scientific constructs. This communication presents a critical reflection on the use of the term ‘load’ in sport and exercise science. We present ways in which the use of this term breaches principles of science and provide practical solutions for ongoing use in research and practice.

**KEYWORDS:** exercise, definition, nomenclature, terminology, SI

Misuse of the term 'load' in sport and exercise science

## INTRODUCTION

Sport and exercise science is the *scientific* study of factors that influence the ability to perform exercise.[1] Importantly, terms and nomenclature used to describe exercise should abide by the Système International d'Unités (SI).[2] Yet for decades there has been ongoing debate regarding misuse use of terminology in sport and exercise science.[1-6] For example, Knuttgen and Kraemer[5] reminded sport and exercise scientists that an isometric muscle 'contraction' is not possible. The term 'contraction' means to shorten and in isometric activity there is no movement. Hence the term isometric muscle action is preferred.[5]

Sport and exercise scientists have also commonly been guilty of misusing mechanical terms such as force, weight, work and power.[1, 3] Winter[6] appropriately highlighted that one such term that is often misused in sport and exercise science is 'workload'. Despite its shortcomings, this term is still frequently used to describe the volume and/or intensity of exercise performed in sport and exercise science research (e.g., [7, 8, 9]).

The issue with the term is the simultaneous misuse of two separate mechanical constructs, 'work' and 'load'. The term 'work' is derived from the idea that mechanical work was performed and is calculated as the product of the distance (m) through which a force (N) is applied. The SI unit of work is the joule (J) and should not be presented in any unit other than joules.[2] Research that presents 'work' in units other than joules is simply incorrect and does not abide by principles of science or the SI. Moreover, Winter[6] suggested that the 'load' component of the term refers to the resistance experienced during the performance of the work, and hence should be referred to as a force, which has the SI-derived unit of the newton (N). Accordingly, the scientific use of the term 'workload' is completely nonsensical and should be "banished from the lexicon of exercise sciences."[2, 6]

However, it seems that the message hasn't been adhered to by sport and exercise scientists. More than ever, studies are being published with the use of the term 'workload' and/or incorrect use of the term 'work'. A consensus statement published in the *International Journal of Sports Physiology and Performance* is guilty of making these common errors.[10]

*“…external training loads are objective measures of the work performed by the athlete during training or competition and are assessed independently of internal workloads. Common measures of external load include power output, speed, acceleration, time–motion analysis, global positioning system (GPS) parameters, and accelerometer-derived parameters.”*

Bourdon et al., [10]

The above statement includes a number of errors. First, the authors’ explicitly use the term ‘workload’. Second, the authors state that “external training loads are objective measures of the work performed”. Yet none of the examples provided (e.g., power output, speed) are objective measures that would obtain outputs measured in joules. In fact, power output (one of the examples provided) is a measure of the rate at which work is performed, measured in joules per second, and otherwise defined in the SI-derived unit of the watt (W).

In spite of the publication ‘”Workload” – time to abandon?’[6] some studies have still slipped through the cracks and have been published using incorrect terminology (e.g., [11, 12-14]). In some cases, the term ‘workload’ is even used in the article title (e.g., [8, 15, 16]).

In addition to the misuse of ‘work’ and ‘workload’, a growing concern is the incorrect use of the term ‘load’ in sport and exercise science. Terms such as ‘training load’ are becoming increasing popular when describing exercise volume and/or intensity in sport and exercise science (e.g., [17, 18, 19]). This is not helped when leading manufacturers of wearable athlete tracking devices incorrectly use mechanical terms to label their proprietary metrics. An example of this is PlayerLoad™, a popular accelerometer-derived metric reported in arbitrary units. Terms such as ‘body load’,[20, 21] ‘running load’,[22, 23] and ‘physical load’ have also been used.[24, 25] In addition, the term ‘load’ is used across a range of disciplines, not only sport and exercise science. For example, ‘allostatic load’[26] and ‘cognitive load’[27] have also become commonly accepted terms.

As Winter[6] outlines, a 'load' is a mechanical variable that, when used appropriately, describes a force and therefore should be accompanied with the SI-derived unit of the newton, which has the symbol N. A 'load' presented in any other unit, including arbitrary units, is incorrect and does not abide by the principles of science and the SI.[28]

Appropriate use of definitions and the SI is important because it enables common understanding and forms the basis for science.[29] It is tempting to accept popular terms and nomenclature as scientific. However, scientists are obliged to abide by the SI and must pay close attention to mechanical and scientific constructs.[2, 29] Accordingly, the purpose of this communication is to present a critical reflection on the use of the term 'load' in the sport and exercise science domain. We present ways in which the use of this term breaches the principles of science, and importantly, we provide practical solutions for ongoing use in research and practice.

**THE TERM 'LOAD'**

The term 'load' in sport and exercise science is very broad, simplistic and might be easily confused because of multiple definitions in the fields of structural and electrical physics. *'Load'* is a term frequently used in engineering, defined as 'the force exerted on a surface or body'.[30] For example, the load on an arch or bridge. 'Load' can also be considered as the overall force to which a structure is subjected in supporting a mass or in resisting externally applied forces.[30] In this case 'load' should have the accompanying SI derived unit of the newton (N) because it is considered as an expression of force. Furthermore, in electrical physics, 'load' is a term used to describe a component or portion of a circuit, which consumes electric power. In electric power circuits, examples of 'load' are any part of a circuit that consumes electrical power, such as appliances and lights. The term 'load' can also refer to cumulative resistance of an electrical circuit, which is measured in the SI-derived unit the ohm and has the symbol Ω. Hence, the use of the term 'load' in sport and exercise science is problematic, due to multiple definitions in varying fields of science.

Indeed, the term 'load' can also have non-scientific definitions. The Oxford English Dictionary defines 'load' in a number of different ways. For example, 'load' is defined as a countable noun, which describes "something that is being carried (usually in large amounts) by a person, vehicle, etc.".[31] For example, "the truck is carrying a heavy load". However, 'load' can also represent a burden placed on a person, structure, machine or system and is defined as, "an amount of work that a person or machine has to do".[31] For example, "She has a heavy teaching load."

It is this second definition that causes confusion, especially when it comes to science. Where the first definition describes something to be carried, i.e., a mass or weight (which ultimately can be represented as a force), the second describes work. As discussed above, in science, this must be accompanied with the unit of joules. In these instances, the term 'demand' or 'burden' are better suited because they avoid the misuse of scientific constructs. For example, "She has a heavy teaching burden". Nevertheless, it is this definition of 'load' where the idea for use of the term 'training load' comes from.

## 'TRAINING LOAD'

The most commonly adopted term throughout the sport and exercise science literature used to describe exercise is 'training load'. Generally, sport and exercise scientists agree that 'training load' consists of both 'external' and 'internal' domains.[10, 32, 33] Typically, the term 'external training load' has been referred to as the total amount of mechanical or locomotive stress generated by an athlete during exercise (e.g., distance travelled, total number of pitches thrown in baseball or the number of jumps a volleyball player undertakes).[17] Meanwhile, 'internal training load' is typically referred to as the physiological and psychological stress (e.g., rating of perceived exertion [RPE], heart rate [HR]) imposed on the athlete in response to the 'external training load'.[10, 33]

However, there is much ambiguity in what this term or construct represents. The term 'training load' appears to be related to the amount (volume) of exercise or training completed.[10, 32-35] Other authors have defined 'training load' as the product of volume and intensity of exercise.[36] Others have suggested that 'training load' is defined as the amount of stress placed on an individual in response to exercise over a period of time.[37, 38] Nevertheless, there does not appear to be any clear definition of what construct 'training load' represents and accordingly there are many inconsistencies in descriptions of 'training load' in the sport and exercise science literature.

For example, several researchers (e.g., [36, 39]) have used session RPE or HR-based 'TRIMP' as measures of 'training load'. These metrics are the product of an intensity factor (RPE or HR [weighted based on value]) and an exercise duration factor (minutes). In these instances, it appears that 'training load' represents the construct of exercise volume. But to add confusion, other researchers have quantified 'training load' by simultaneously reporting measures of both volume and intensity. For example, Casamichana et al.[40] quantify 'external load' as running distances (volume). However, they also quantify 'external load' as a frequency of efforts at high running speeds (intensity). Bartlett et al.[41] quantify 'training load' as running distance (volume) as well as mean speed in metres per minute (intensity). Ritchie et al.[42] associated 'training load' with total distance (volume), but also average movement speed in metres per minute (intensity), and Boyd[43] associated 'external load' with PL·min$^{-1}$ (intensity). To further add confusion, an International Olympic Committee consensus statement refers to 'external load' as exercise duration (e.g., seconds, minutes, hours) as well as exercise frequency (e.g., number of sessions completed).[44] These are just a few examples of a litany of errors throughout the literature where 'training load' represents multiple constructs. We are not aware of any other field of science where different constructs are combined into a meta-construct, like 'training load'.

The use of a meta-construct such as 'training load' is simply not necessary, especially given modern computing power means that sport and exercise scientists have no conceptual or analytical requirement to amalgamate separate training constructs (intensity, frequency, duration). Furthermore, researchers have observed that amalgamation of these training constructs might actually misrepresent the exercise session completed by athletes because the contributions of the separate constructs to adaptation or injury risk are not necessarily equal.[45, 46] Nevertheless, we acknowledge that doing so might present a more practically viable metric for reporting to coaches and athletes. In the following sections we discuss the appropriateness of the term 'exercise volume' for this purpose and provide clear definitions to avoid confusion with mechanical properties defined in the SI, as well as avoiding issues related to a single term representing multiple constructs.

Misuse of the term ‘load’ in sport and exercise science

In addition to the ambiguity of the term ‘training load’, the misuse of the mechanical term ‘load’ is problematic. If exercise is expressed as a ‘load’, there should be a measure of newtons produced. As discussed above, it is not uncommon for sports scientists to report ‘external training load’ as distances, speeds or even as arbitrary units derived from accelerometers (e.g., [34, 35, 47, 48]). Furthermore, ‘internal training load’ is commonly reported in arbitrary units derived from the product of exercise duration and RPE or HR (e.g., [34, 35, 47]). In these instances, the term ‘training load’ is a misnomer. The use of newtons cannot occur, despite the fact that these activities do require considerable use of force. Therefore, the reporting of this activity is incorrect, as it does not abide by basic principles of science or the SI. Moreover, although outside the scope of this communication, the use of the term ‘impulse’ is also commonly misused when referring to the product of exercise duration and HR.[49, 50] Impulse is a physical variable which represents the product of force and time and has the SI-derived unit of the newton second (N·s). For more information on the misuse of this term in exercise science please refer to the following communication from Winter et al.[1]

**PLAYERLOAD™**

The use of wearable technology in sport and exercise science has become common practice in recent years. In particular, the adoption of triaxial accelerometers for monitoring exercise volume and intensity in sport and exercise science is becoming increasing popular.[10, 51] This is because triaxial accelerometers measure movements in three orthogonal planes of motion, have high sampling frequencies and are sensitive to contact based elements of sports (e.g., tackling), not just locomotive activity.[52] Consequently, triaxial accelerometers have been used as a tool to quantify exercise volume and intensity in sports, such as basketball,[53] soccer[34] and Australian football.[54, 55]

The most common accelerometry-derived metric used by sports scientists, coaches and researchers is a modified vector magnitude algorithm, termed PlayerLoad™ (PL). It has been reported that PL is calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three orthogonal planes and divided by 100 (Equation 1).[52]

$$PlayerLoad^{TM} = \frac{\sqrt{((a_{x1} - a_{x-1})^2 + (a_{y1} - a_{y-1})^2 + (a_{z1} - a_{z-1})^2)}}{100}$$

**Equation 1.** PlayerLoad™ algorithm (developed by Catapult Sports, Melbourne, Australia). *$a_x$ = mediolateral accelerometer; $a_y$ = anteroposterior accelerometer; $a_z$ = vertical accelerometer.*[52]

Researchers have reported that PL has excellent reliability in both laboratory and field settings (coefficient of variation <2%).[52] Further, a number of researchers have claimed the construct validity of PL by establishing strong correlations to other constructs of exercise volume.[34, 35] Additionally, PL per minute (PL·min$^{-1}$) has been commonly used as a measure of exercise intensity across a range of sports, such as Australian football, netball and basketball.[53-55]

Although PL and PL·min$^{-1}$ appear to be promising metrics for assessing exercise volume and intensity, respectively, these metrics have a number of limitations. These limitations are typically centred around the proprietary nature of PL. Besides the provided formula (Equation 1), limited details pertaining to the computation of PL has been provided by the device manufacturer. For example, it is unclear why the PL formula calculates the instantaneous rate of change of acceleration (otherwise known in classical physics as 'jerk'). Besides the fact that PL increases with more movement, there is no proof of concept that this method is appropriate to quantify human movement.

Inconsistencies with typical scientific practice and the proprietary nature of PL likely explain why large variations in the definitions and calculations for PL have been identified throughout the literature.[56] Furthermore, researchers have reported that the PL calculated from the device manufacturer software differs to the PL calculated from the described formula (Equation 1), indicating additional data manipulation prior to the output.[57] A lack of transparency from device manufacturers regarding data filtering and analysis techniques is problematic because this limits comparison between studies and reproducibility of research. A greater understanding of the exact methods of calculating PL would improve the usefulness of this metric in research and practice.

Finally, and perhaps most importantly, the term PlayerLoad™ is inappropriate. The misuse of the mechanical term 'load' is problematic and breaches principles of science. As mentioned above, the PL formula is a calculation of mechanical 'jerk' (rate of change of acceleration), which should be reported in the unit $m \cdot s^{-3}$. Despite this, PL is reported in arbitrary units (i.e., units that do not materially matter). This is problematic for two reasons. First, a player 'load' should be reported as a force, which is expressed in newtons (N), not in arbitrary units. Second, data obtained from an accelerometer naturally has an SI unit, which is metres per second squared ($m \cdot s^{-2}$). Therefore, there is no reason why data obtained from an accelerometer be reported in arbitrary units. Further, it is possible to express exercise using accelerometers as SI units such as force (N)[58-60] or impulse ($N \cdot s$)[60-62] given the body mass of the athlete is known and accelerations are captured at the centre of mass. For this reason, it is recommended to capture accelerations at the centre of mass. However, in some instances this might not be possible. In this case, caution should be used when interpreting body segment accelerations rather than overall dynamic body accelerations.

All of these issues with PL are in addition to problems already associated with measurements reported in arbitrary units. It is very common for researchers to abbreviate arbitrary units as AU or a.u. However, these abbreviations are not recommended because they conflict with abbreviations used for astronomical units. The astronomical unit (AU) is a unit of length, equal to the distance from the Earth to the Sun, roughly 150 million kilometres. For this reason, certain members of the International Science Council recommend that the abbreviation of arbitrary units be reported as arb. u or p.d.u (procedure defined unit).[63]

## SOLUTION

The American College of Sports Medicine (ACSM), the world's largest sport and exercise science professional organisation, suggests the use of the terms frequency (F), intensity (I), time (T), and type (T) for exercise monitoring and prescription (known as the FITT principle).[64] More recently, this concept has been expanded to include volume (V) and progression (P; FITT-VP), where exercise volume represents the product of exercise intensity, exercise time and exercise frequency (Equation 2).[64, 65] Table 1 provides definitions of these terms.

$$Exercise\ Volume = Exercise\ Intensity\ \times Exercise\ Time\ \times Exercise\ Frequency$$

**Equation 2.** Calculation of Exercise Volume.[64]

*** Table 1 here ***

The term 'intensity' is particularly appropriate when describing how hard somebody is exercising and is a fitting way to avoid misuse of mechanical constructs such as 'load' and 'work'.[1, 2] We acknowledge that the term 'luminous intensity' is defined in the base SI (https://www.nist.gov/pml/weights-and-measures/si-units-luminous-intensity). Luminous intensity is the term used to describe the luminescence of light, in the units of candela (cd). Although this might be confusing to the sport and exercise scientist, the point is that 'intensity' itself is not a universally defined term, and moreover, 'exercise intensity' is not defined in the base SI. The appropriateness of 'intensity' to express the effort of exercise was first promoted by Knuttgen[3] and later again by Winter.[1]

Intensity can be universally applied to all situations and multiple disciplines, and can be expressed in absolute or relative terms. Further, intensity can be quantified in internal or external constructs (Figure 1). The difference in measurement between internal and external exercise intensity is the unit used to quantify intensity. For example, in running or swimming, speed of movement could be an expression of absolute external exercise intensity, which is measured in the SI-derived unit metres per second ($m \cdot s^{-1}$). Power (W), acceleration ($m \cdot s^{-2}$) and force (N) are also potentially useful expressions of absolute external exercise intensity in sports such as cycling or rowing. Measures of absolute internal exercise intensity include physiological responses such as oxygen consumption ($\dot{V}O_2$) expressed in litres per minute ($L \cdot min^{-1}$) or HR measured in beats per minute ($b \cdot min^{-1}$).

Intensity may also be expressed in a relative manner, such as subjective RPE or percentages of maximums, which can be described in categories such as low, moderate and high.[2, 66] It is also possible to apply weighting factors to exercise intensity. Some previous approaches have been to apply intensity weighting factors according to the relationship between fractional elevation in heart rate and blood lactate concentration.[47, 67] Some examples of relative external exercise intensity are percentages of maximum running speed. Some examples of relative internal exercise intensity are RPE and percentages of $HR_{max}$ or $\dot{V}O_{2max}$.[2, 66]

*** Figure 1 here ***

Exercise volume is quantified as the product of exercise intensity, exercise duration and frequency.[64] When the exercise volume of only one exercise session is of interest, the product of exercise intensity and duration can be easily calculated because the frequency is equal to one. For example, the product of speed ($m\cdot s^{-1}$) and duration (s) is distance (m) and the product of force (N) and duration (s) is impulse (N·s).[68]

The use of non-SI units or dimensionless units such as percentages for calculating exercise intensity or volume is possible, but care must be taken not to use incorrect terminology. For example, the session rating of perceived exertion (s-RPE), which is the product of exercise duration (s) and RPE, is probably the most widely used metric in sport and exercise science.[69] Additionally, the product of exercise duration (s) and HR (bpm) is also commonly used.[49, 50, 67] Undoubtably, these metric holds great practical application for sport and exercise scientists. However, these metrics should not be referred to as training 'load' (nor 'Impulse') because there is no measurement of force.

Finally, it should be noted that although the ACSM terms and definitions are preferable, they also frequently use the term 'load' in their position stands (e.g., [70, 71]). Inconsistencies and variations in the terms used by the ACSM are problematic. Regardless, this communication provides recommendations for sport and exercise scientists to avoid the misuse of mechanical terms in order to conduct their practice from a firmer scientific base.

**CONCLUSION**

Misuse of the term 'load' in sport and exercise science

As members of a scientific discipline, we are collectively guilty of misusing the terms 'work', 'workload', 'training load' and 'load'. However, the development of sport and exercise science now requires that the principles of science and the SI be upheld, and as such, our use of these terms needs to end. The descriptions and reporting of exercise and training should make correct use of scientific terms, nomenclature and units. Accordingly, the term 'training load' is unscientific and should therefore be abandoned. The terms 'volume' and 'intensity', suggested by the ACSM, are logical and avoid misuse of mechanical constructs. Further, they are more suitable than 'training load' and clearly describe separate constructs. The term 'intensity' is appropriate for describing how hard somebody is exercising.[1, 2] In addition, the term 'volume' is appropriate to describe the total amount of exercise performed and avoids misuse of scientific constructs such as 'work' and 'load'. Importantly, journal editors and reviewers should be critical of research which uses incorrect terms and should uphold principles of science and the SI. Authors and readers should be guided to the correct use of scientific terms, nomenclature and units. Adoption of the recommendations from this communication will help to advance sport and exercise science and permit practitioners to adopt research recommendations from a firmer scientific base.

**REFERENCES**


1. Winter EM, Abt G, Brookes F, et al. Misuse of "Power" and other mechanical terms in Sport and Exercise Science Research. *J. Strength. Cond. Res.* 2015; 30(1):292-300.
2. Winter EM, Fowler N. Exercise defined and quantified according to the Systeme International d'Unites. *J. Sports Sci.* 2009; 27(5):447-460.
3. Knuttgen H. Force, Work, Power, and Exercise. *Med. Sci. Sports.* 1978; 10(3):227-228.
4. Knuttgen H. Measurement and terminology for authors and reviewers. *The Journal of sports medicine and physical fitness.* 2019; 59(2):341-342.
5. Knuttgen H, Kraemer W. Terminology and measurement. *Journal of applied sport science research.* 1987; 1(1):1-10.
6. Winter EM. " Workload"--time to abandon? *J. Sports Sci.* 2006; 24(12):1237-1238.
7. Gabbett TJ, Hulin BT, Blanch P, Whiteley R. High training workloads alone do not cause sports injuries: how you get there is the real issue. *Br. J. Sports Med.* 2016:bjsports-2015-095567.
8. Lukonaitienė I, Kamandulis S, Paulauskas H, et al. Investigating the workload, readiness and physical performance changes during intensified 3-week preparation periods in female national Under18 and Under20 basketball teams. *J. Sports Sci.* 2020; 38(9):1018-1025.
9. Udby CL, Impellizzeri FM, Lind M, Nielsen RØ. How has workload been defined and how many workload-related exposures to injury are included in published sports injury articles? A scoping review. *J. Orthop. Sports Phys. Ther.* 2020; 50(10):538-548.
10. Bourdon PC, Cardinale M, Murray A, et al. Monitoring athlete training loads: consensus statement. *Int. J. Sports Physiol. Perform.* 2017; 12(s2):S2-161-S162-170.
11. Scanlan A, Dascombe B, Reaburn P. A comparison of the activity demands of elite and sub-elite Australian men's basketball competition. *J. Sports Sci.* 2011; 29(11):1153-1160.
12. Jowitt HK, Durussel J, Brandon R, King M. Auto detecting deliveries in elite cricket fast bowlers using microsensors and machine learning. *J. Sports Sci.* 2020; 38(7):767-772.
13. Van Hooren B, Goudsmit J, Restrepo J, Vos S. Real-time feedback by wearables in running: Current approaches, challenges and suggestions for improvements. *J. Sports Sci.* 2020; 38(2):214-230.
14. Casamichana D, Castellano J. Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J. Sports Sci.* 2010; 28(14):1615-1623.
15. Springham M, Williams S, Waldron M, Strudwick AJ, Mclellan C, Newton RU. Prior workload has moderate effects on high-intensity match performance in elite-level professional football players when controlling for situational and contextual variables. *J. Sports Sci.* 2020; 38(20):2279-2290.
16. Hiscock DJ, Dawson B, Clarke M, Peeling P. Can changes in resistance exercise workload influence internal load, countermovement jump performance and the endocrine response? *J. Sports Sci.* 2018; 36(2):191-197.
17. 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.
18. McLaren SJ, Macpherson TW, Coutts AJ, Hurst C, Spears IR, Weston M. The relationships between internal and external measures of training load and intensity in team sports: a meta-analysis. *Sports Med.* 2018; 48(3):641-658.
19. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int. J. Sports Physiol. Perform.* 2019; 14(2):270-273.
20. Barron DJ, Atkins S, Edmundson C, Fewtrell D. Accelerometer derived load according to playing position in competitive youth soccer. *Int. J. Perf. Anal. Spor.* 2014; 14(3):734-743.
21. McLean BD, Cummins C, Conlan G, Duthie G, Coutts AJ. The fit matters: influence of accelerometer fitting and training drill demands on load measures in rugby league players. *Int. J. Sports Physiol. Perform.* 2018; 13(8):1083-1089.

22. Colby MJ, Dawson B, Heasman J, Rogalski B, Gabbett TJ. Accelerometer and GPS-derived running loads and injury risk in elite Australian footballers. *J. Strength. Cond. Res.* 2014; 28(8):2244-2252.
23. Buchheit M. Managing high-speed running load in professional soccer players: The benefit of high-intensity interval training supplementation. *Sport Perform. Sci. Reports.* 2019; 53:1-5.
24. Kozina Z, Iermakov S, Creţu M, Kadutskaya L, Sobyanin F. Physiological and subjective indicators of reaction to physical load of female basketball players with different game roles. *J Phys. Educ. Sport.* 2017; 17(1):378.
25. Fischer-Sonderegger K, Taube W, Rumo M, Tschopp M. Measuring Physical Load in Soccer: Strengths and Limitations of 3 Different Methods. *Int. J. Sports Physiol. Perform.* 2019; 14(5):627-634.
26. McEwen BS, Wingfield JC. What's in a name? Integrating homeostasis, allostasis and stress. *Horm. Behav.* 2010; 57(2):105.
27. Paas FG, Van Merriënboer JJ. Variability of worked examples and transfer of geometrical problem-solving skills: A cognitive-load approach. *J. Educ. Psychol.* 1994; 86(1):122.
28. Renner T. *Quantities, units and symbols in physical chemistry*, Royal Society of Chemistry; 2007.
29. Ruddock A, Copeland R, Broom D, Wheat J. Winter's Principles of Sport and Exercise Science. *The Sport and Exercise Scientist.* 2020(66):16-17.
30. Rodgers MM, Cavanagh PR. Glossary of biomechanical terms, concepts, and units. *Phys. Ther.* 1984; 64(12):1886-1902.
31. Stevenson A. *Oxford dictionary of English*, Oxford University Press, USA; 2010.
32. Impellizzeri FM, Rampinini E, Marcora SM. Physiological assessment of aerobic training in soccer. *J. Sports Sci.* 2005; 23(6):583-592.
33. Halson SL. Monitoring Training Load to Understand Fatigue in Athletes. *Sports Med.* 2014; 44(2):139-147.
34. Scott B, Lockie RG, Knight TJ, Clark AC, De Jonge X. A comparison of methods to quantify the in-season training load of professional soccer players. *Int J Sports Physiol Perform.* 2013; 8(2):195-202.
35. Scott T, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J. Strength Cond. Res.* 2013; 27(1):270-276.
36. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med. Sci. Sports Exerc.* 2004; 36(6):1042-1047.
37. Jaspers A, Brink MS, Probst SG, Frencken WG, Helsen WF. Relationships between training load indicators and training outcomes in professional soccer. *Sports Med.* 2017; 47(3):533-544.
38. Eckard TG, Padua DA, Hearn DW, Pexa BS, Frank BS. The relationship between training load and injury in athletes: a systematic review. *Sports Med.* 2018; 48(8):1929-1961.
39. Manzi V, D'Ottavio S, Impellizzeri FM, Chaouachi A, Chamari K, Castagna C. Profile of weekly training load in elite male professional basketball players. *The Journal of Strength and Conditioning Research.* 2010; 24(5):1399-1406.
40. Casamichana D, Castellano J, Calleja-Gonzalez J, San Román J, Castagna C. Relationship between indicators of training load in soccer players. *J. Strength. Cond. Res.* 2013; 27(2):369-374.
41. Bartlett JD, O'Connor F, Pitchford N, Torres-Ronda L, Robertson SJ. Relationships between internal and external training load in team-sport athletes: evidence for an individualized approach. *Int. J. Sports Physiol. Perform.* 2017; 12(2):230-234.
42. Ritchie D, Hopkins WG, Buchheit M, Cordy J, Bartlett JD. Quantification of training and competition load across a season in an elite Australian football club. *Int. J. Sports Physiol. Perform.* 2016; 11(4):474-479.

43. Boyd LJ, Ball K, Aughey RJ. Quantifying external load in Australian football matches and training using accelerometers. *Int. J. Sports Physiol. Perform.* 2013; 8(1):44-51.
44. 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.
45. Renfree A, Casado A, McLaren S. Re-thinking athlete training loads: would you rather have one big rock or lots of little rocks dropped on your foot? *Res. Sports Med.* 2021:1-4.
46. Weaving D, Dalton-Barron N, McLaren S, et al. The relative contribution of training intensity and duration to daily measures of training load in professional rugby league and union. *J. Sports Sci.* 2020; 38(14):1674-1681.
47. Akubat I, Barrett S, Abt G. Integrating the internal and external training loads in soccer. *Int. J. Sports Physiol. Perform.* 2014; 9(3):457-462.
48. Weaving D, Marshall P, Earle K, Nevill A, Abt G. Combining internal-and external-training-load measures in professional rugby league. *Int. J. Sports Physiol. Perform.* 2014; 9(6):905-912.
49. Banister E. Modeling elite athletic performance, in *Physiological testing of elite athletes*. MacDougall J, Wenger H, Green H, ed^eds. Champaign, IL, Human Kinetics, 1991.
50. Edwards S. High performance training and racing. In:, in *The heart rate monitor book*ed^eds. Sacramento, CA, Feet Fleet Press, 1993.
51. Fox JL, Scanlan AT, Stanton R. A review of player monitoring approaches in basketball: current trends and future directions. *J. Strength. Cond. Res.* 2017; 31(7):2021-2029.
52. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Physiol Perform.* 2011; 6(3):311-321.
53. Fox JL, Stanton R, Scanlan A. A Comparison of Training and Competition Demands in Semiprofessional Male Basketball Players. *Res. Q. Exerc. Sport.* 2018; 89(1):103-111.
54. Cormack S, Mooney MG, Morgan W, McGuigan MR. Influence of Neuromuscular Fatigue on Accelerometer Load in Elite Australian Football Players. *Int. J. Sports Physiol. Perform.* 2013; 8(4):373-378.
55. Mooney MG, Cormack S, O'Brien BJ, Morgan WM, McGuigan M. Impact of neuromuscular fatigue on match exercise intensity and performance in elite Australian football. *J. Strength Cond. Res.* 2013; 27(1):166-173.
56. Bredt SdGT, Chagas MH, Peixoto GH, Menzel HJ, de Andrade AGP. Understanding player load: Meanings and limitations. *J. Hum. Kinet.* 2020; 71:5.
57. Nicolella DP, Torres-Ronda L, Saylor KJ, Schelling X. Validity and reliability of an accelerometer-based player tracking device. *PLoS One.* 2018; 13(2).
58. Staunton C, Wundersitz D, Gordon B, Kingsley M. Construct validity of accelerometry-derived force to quantify basketball movement patterns. *Int. J. Sports Med.* 2017; 38(14):1090-1096.
59. Staunton C, Wundersitz D, Gordon B, Kingsley M. Accelerometry-derived relative exercise intensities in elite women's basketball. *Int. J. Sports Med.* 2018; 39(11):822-827.
60. Palmer J, Wundersitz D, Bini R, Kingsley M. Effect of Player Role and Competition Level on Player Demands in Basketball. *Sports.* 2021; 9(3):38.
61. Staunton C, Wundersitz D, Gordon B, Custovic E, Stanger J, Kingsley M. The effect of match schedule on accelerometry-derived exercise dose during training sessions throughout a competitive basketball season. *Sports.* 2018; 6(3):69.
62. Staunton C, Wundersitz D, Gordon B, Kingsley M. Discrepancies Exist between Exercise Prescription and Dose in Elite Women's Basketball Pre-Season. *Sports.* 2020; 8(5):70.
63. Olesen H. Properties and units in the clinical laboratory sciences-I. Syntax and semantic rules (IUPAC-IFCC Recommendations 1995). *Pure Appl. Chem.* 1995; 67(8-9):1563-1574.
64. Pescatello LS, Arena R, Riebe D, Thompson PD. *ACSM's guidelines for exercise testing and prescription,* 9th ed, Philadelphia, Wolters Kluwer Health/Lippincott Williams & Wilkins; 2014.

65. Bushman BA. Developing the P (for Progression) in a FITT-VP Exercise Prescription. *ACSM's Health & Fitness Journal.* 2018; 22(3):6-9.
66. Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med. Sci. Sports Exerc.* 2001; 33(6; SUPP):S364-S369.
67. Manzi V, Iellamo F, Impellizzeri F, D'Ottavio S, Castagna C. Relation between individualized training impulses and performance in distance runners. *Med Sci Sports Exerc.* 2009; 41(11):2090-2096.
68. Hall SJ, Lysell D. *Basic biomechanics*, St. Louis, MO, Mosby Inc.; 1995.
69. Foster C, Boullosa D, McGuigan M, et al. 25 Years of Session Rating of Perceived Exertion: Historical Perspective and Development. *Int. J. Sports Physiol. Perform.* 2021; 1(aop):1-10.
70. Ratamess NA, Alvar BA, Evetoch TE, et al. Progression models in resistance training for healthy adults. *Med. Sci. Sports Exerc.* 2009; 41(3):687-708.
71. Kohrt W, Bloomfield S, Little K, Nelson M, Yingling V. Physical activity and bone health. Position stand of the American College of Sports Medicine. *Med Sci Sports Exerc.* 2004; 36:1985-1996.

**TABLE AND FIGURE LEGENDS**

**Table 1.** Key terminology that should be used when monitoring and prescribing exercise.

*HR = heart rate; $HR_{max}$ = maximum heart rate; $\dot{V}O_2$ = oxygen consumption; $\dot{V}O_{2max}$ = maximum oxygen consumption.*

**Figure 1.** Internal and external outcomes commonly used to measure absolute and relative exercise intensity.

*RPE = rating of perceived exertion, $HR_{max}$ = maximum heart rate; $\dot{V}O_{2max}$ = maximum oxygen consumption.*

**Acknowledgments**

The authors acknowledge the work of Professor Edward Winter who was the inspiration for writing this manuscript. No external financial support was used for this study.

**Declaration of Interest**

The authors have no competing interests to declare

**Ethical Compliance**

Ethical compliance is not relevant for this review article as there were no human or animal research participants.

**Funding Information**

No external financial support was used for this study.

**Table 1.** Key terminology that should be used when monitoring and prescribing exercise.

| Term | Definition |
|---|---|
| **Exercise volume** | The product of exercise intensity, time and frequency (Pescatello et al., 2014). |
| **Exercise intensity** | The specific level of muscular activity that can be quantified in terms of power (rate of energy expenditure), force, or velocity (Winter & Fowler, 2009). Exercise intensity can be quantified in absolute and relative terms and measured in internal or external units (e.g., external = locomotor and mechanical; internal = physiological). |
| **Absolute intensity** | Exercise intensity independent of an individual's physical capacity (e.g., absolute internal intensity: $\dot{V}O_2$; absolute external intensity: running speed). |
| **Relative intensity** | Exercise intensity specific to the individual's physical capacity (e.g., Relative Internal Intensity: % $HR_{max}$, % $\dot{V}O_{2max}$; relative external intensity: % maximum running speed). |
| **Frequency** | The number of exercise or training sessions per day, week or month (Pescatello et al., 2014). |
| **Time** | The duration of the exercise session or match (Pescatello et al., 2014). |
| **Type** | The mode of activity being performed, such as running, cycling or swimming (Pescatello et al., 2014). |
| **Progression** | The advancement of the exercise program through a gradual increase in exercise volume/intensity. This is achieved by adjusting exercise duration, frequency and/or intensity until the desired exercise goal is reached (Bushman, 2018). |
| **Adaptation** | The process of change in the physical and physiological systems in response to exercise. With adaptation the body will positively adapt to each of the acute exercise variables. With maladaptation the body negatively adapts due to fatigue and overtraining. |

*HR = heart rate; $HR_{max}$ = maximum heart rate; $\dot{V}O_2$ = oxygen consumption; $\dot{V}O_{2max}$ = maximum oxygen consumption.*

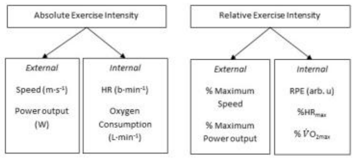
Absolute Exercise Intensity
Relative Exercise Intensity
External
Speed (m·s⁻¹)
Power output (W)
Internal
HR (b·min⁻¹)
Oxygen Consumption (L·min⁻¹)
External
% Maximum Speed
% Maximum Power output
Internal
RPE (arb. u)
%$HR_{max}$
% $\dot{V}O_{2max}$

Figure 1