WORK SMARTER NOT HARDER: MECHANICAL WORK AS A MEASURE OF ATHLETE WORKLOAD

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A thorough understanding of competition workloads is necessary to optimize athlete readiness. The purpose of this study was to investigate the contribution of mechanical work within a measure of workload (session-RPE) in women's rugby sevens. Data from 22 international athletes, participating in 103 matches were gathered, with a total of 1108 complete datasets available for analysis. GPS-monitors worn by athletes gathered data on time and speed. Overall absolute game mechanical work and session-RPE (sRPE) values were calculated. A linear mixed model evaluated the contribution of overall game work to sRPE by athlete. A strong significant association was found between sRPE and overall game work ($R^2_{conditional}$=69.3, p<0.01). Ultimately, the investigation demonstrated that mechanical work may be a suitable surrogate for the more holistic measure of sRPE.

KEYWORDS: football codes, women's sport, contact sport, load monitoring

INTRODUCTION: Understanding the workloads that athletes experience in competition provides important benchmarks for optimizing preparedness (Mujika, 2013; Haddad et al., 2017; Gabbett, 2016). Monitoring athlete workload may be accomplished using a variety of tools, and while there is no gold-standard method applicable across sports, the use of session-rating of perceived exertion (sRPE) is widely popular (Haddad et al., 2017, Mujika, 2013; Foster et al., 2001; Gabbett, 2016). The sRPE metric represents a holistic measure of workload and is the product of an athlete's subjective self-reported rating of perceived exertion (RPE) and the duration of the session in minutes (Haddad et al., 2017). sRPE has been shown to have relationships to other internal performance workload measures, like training impulse (TRIMP), including Bannister's, Lucia's, Edwards' TRIMP, and external performance workload measures like total and high-speed distance (Haddad et al., 2017).

While sRPE is popular across sports, its holistic nature means that individual objective factors and their specific impact on athlete workload are not clearly identified when using this metric alone (Haddad et al., 2017). For example, apart from a measure of duration, sRPE does not overtly highlight the mechanical work performed by the athlete. Given the potential to quantify mechanical workload from GPS derived kinematics there exists a unique opportunity to evaluate the contribution of athlete mechanical work to an athlete's overall experience and help to specify what mechanical factors may contribute to athlete workload. Quantifying athlete workload through objective, salient factors available in the competition environment should provide an enhanced approach to workload monitoring which is especially important given the ties between athlete workload and optimal performance as well as injury risk (Mujika, 2013; Gabbett, 2016).

Precedence for this comes from previous investigations using GPS data to quantify kinematics that drive athlete workload in men's rugby and women's soccer (Haddad et al., 2017; Mujika, 2013; Delaney et al., 2018; Mara et al., 2016; Staunton et al., 2022). It is possible to consider that mechanical work may in fact provide a useful objective metric to substantiate the competitive demands of rugby sevens both within and external to an athlete's perceived workload metric as mechanical work quantifies the physical efforts exerted by the athlete in the performance of their sport demands (Haddad et al., 2017; Mujika, 2013; Delaney et al., 2018; Mara et al., 2016; Staunton et al., 2022). Therefore, the purpose of this study was to investigate

the contribution of mechanical work within a measure of athlete perceived workload (sRPE) in women's rugby sevens.

METHODS: Twenty-two female athletes in a full-time rugby sevens training program participated (26.5 ± 4.20 years, 169.5 ± 5.90 cm, 70.5 ± 6.43 kg). Participants volunteered for the study and gave their written informed consent to participate. Retrospective analysis of the data collected included GPS-coded measures, athlete mass and self-reported RPE data for 103 international women's sevens matches. Playing time in minutes, distance in metres, and speed in metres per second, were collected from athlete-worn GPS monitors sampling at 10Hz fixed between the shoulder blades in fabric vests (Apex v2.50, StatSports, Newry:UK). Acceleration data, in metres per second squared, were calculated based on speeds from GPS (Python, v3.9.8, python.org). Mass, in kilograms, was collected pre-match using a portable weigh scale (ES-310, Anyload, Burnaby:CAN). Instantaneous mechanical work, in joules, was the product of mass, acceleration, velocity, and 0.1s time increments. Overall absolute game mechanical work (W) was the cumulative sum of the product of instantaneous absolute power (P) and time (t) (Equation 1). Instantaneous absolute power was the product of athlete mass, acceleration, and velocity.

Equation 1: Overall absolute game mechanical work

$$W = \sum_{i=1}^{n} (P_i \cdot \Delta t_i)$$

One RPE value per match was self-reported by athletes using a 0-10 scale, familiar to participants from regular use in training and competition, following each match (roughly 30 minutes after each match). Session-RPE were calculated as the product of the RPE value and playing time (Python, v3.9.8, python.org). With all data incorporated, a total of 1108 complete datasets were available for analysis. A linear mixed effects model was used to determine the influence of overall game work on sRPE by athlete (R version 4.2.1, Vienna, Austria).

RESULTS: On average, athletes played for 11.4 ± 4.75 total minutes, experienced an RPE of 7 ± 1.9 au, and subsequently an sRPE of 79.6 ± 45.59 au per match played.

The model showed a significant main effect of overall game work, $t(21) = 0.002$, $p<0.01$ on the prediction of sRPE. Overall, 69.3% of the variability of sRPE was accounted for by overall game work, $R^2_{conditional} = 0.693$. All results are shown in Table 1.

Table 1: Summary of Model Results

	β	SE	*t*-statistic	*p*-value	Std. Coefficient	SE Std. Coefficient
(Intercept)	-22.891	4.295	-5.3297	<0.01	0	0
Overall Game Work	0.002	<0.01	123.8666	<0.01	0.7529	0.0061

DISCUSSION: The results of the model demonstrate that mechanical work, represented by overall game work, may provide a novel prediction of the competition demands experienced by female rugby sevens athletes. The model showed that mechanical work done in a game is strongly associated with sRPE whereby an increase in mechanical work is associated with an increase in sRPE, as shown by the overall game work standardized coefficient of 0.7529.

This investigation is the first to include mechanical work as a contributing metric of external workload to be compared against a popular workload metric, sRPE in women's rugby sevens. There have been limited applications of the concept of work to measuring athletic performance (Staunton et al., 2022). Similar investigations making use of GPS units rely on proprietary algorithms to illustrate athlete workload and have shown associations with sRPE values (Casamichana et al., 2013; Marynowicz et al., 2020). Unfortunately, the black box nature of

these algorithms makes it difficult to apply a standardized approach to collection, analysis, and reporting of data relevant across sporting populations (Malone et al. 2017; Clarke et al., 2017). Tuft and Kavaliauskas (2020) found a significant, moderate relationship (r=0.329, p<0.01) between sRPE and mechanical work where work was the product of force and total distance male field hockey athletes covered per session.

Athlete workload is considered to involve a duration and an intensity (Haddad et al., 2017). Given that the current study includes time in the calculation of mechanical work (Equation 1), representative of a duration, it is possible to infer that mechanical work may provide an adequate surrogate of athlete workload. Additionally, the inclusion of particular sport-specific features in monitoring athlete workload have been identified as a meaningful way of producing actionable data that can be used to positively influence athlete performance (Mujika, 2013).

CONCLUSION: This study identified a novel method to objectively and non-intrusively monitor athletic performance, or workload, through the calculation of mechanical work. Overall game work was strongly associated with sRPE and as such may provide an alternative measure of workload in women's rugby sevens. The data required to calculate mechanical work comes from sources already common to team sports, GPS units and weigh scales, and does not require athlete self-reporting during intense competition or training periods. Further, the inclusion of velocity, as contributing factor of mechanical work, presents an actionable metric, meaning practitioners may influence the velocity a player is able to express in competition through speed- or skill-specific training. Ultimately, practitioners are encouraged to continue to critically evaluate the use of holistic measures for actionability and applicability to their sport environments, focussing on measurable, salient factors wherever possible to appropriately describe the experiences of the athletes they work with.

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