To Couple or not to Couple? For Acute:Chronic Workload Ratios and Injury Risk, Does it Really Matter?

Authors

Tim J. Gabbett[1,2], Billy Hulin[3,4], Peter Blanch[5,6], Paul Chapman[7], David Bailey[8]

Affiliations

1 Gabbett Performance Solutions, Brisbane, Australia
2 University of Southern Queensland, Institute for Resilient Regions, Ipswich, Australia
3 School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Australia
4 Football Department, St. George Illawarra Dragons Rugby League Football Club, Wollongong, Australia
5 Football Department, Brisbane Lions Football Club, Brisbane, Australia
6 School of Allied Health Sciences, Griffith University, Brisbane, Australia
7 Performance Department, Queensland Cricket, Brisbane, Australia
8 Team Performance, Cricket Australia, Melbourne, Australia

Key words

workload, load management, injury likelihood

accepted 30.05.2019

Bibliography

DOI https://doi.org/10.1055/a-0955-5589
Published online: 2019
Int J Sports Med

ISSN 0172-4622

Correspondence

Prof. Tim J. Gabbett
Gabbett Performance Solutions,
4011 Brisbane,
Australia
tim@gabbettperformance.com.au

ABSTRACT

We examined the association between coupled and uncoupled acute:chronic workload ratios (ACWR) and injury risk in a cohort of 28 elite cricket fast bowlers (mean ± SD age, 26 ± 5 yr). Workloads were estimated using the session rating of perceived exertion (session-RPE). Coupled ACWRs were calculated using a 1-week acute workload and 4-week chronic workload (acute workload was included in the chronic workload calculation), whereas uncoupled ACWRs used the most recent 1-week acute workload and the prior 3-week chronic workload (acute workload was not included in the chronic workload calculation). A nearly perfect relationship ($R^2 = 0.99$) was found between coupled and uncoupled ACWRs. Using a percentile rank method, no significant differences in injury risk were found between the coupled and uncoupled ACWR. Higher ACWRs were associated with increased injury likelihood for both coupled and uncoupled methods, however there were no significant differences in injury risk between coupled and uncoupled ACWRs. Our data demonstrates that both coupled and uncoupled ACWRs produce the same injury likelihoods. Furthermore, our results are consistent with previous studies: higher ACWRs are associated with greater risk, irrespective of whether acute and chronic workloads are coupled or uncoupled.

Introduction

Acute:chronic workload ratios (ACWRs) are common calculations within sport. Initial calculations of acute and chronic workloads have been 'mathematically coupled,' i. e., a chronic workload contains the current week's acute workload [1, 2]. Coupled chronic workloads generate spurious correlations with acute workloads, which hypothetically may lead to biased inferences [1]. In contrast, uncoupled chronic workloads exclude the acute workload of the most recent week.

Windt and Gabbett [2] demonstrated the mathematical interplay of ACWRs that contain either coupled or uncoupled acute and chronic workload values, and provided regression equations for practitioners to convert between coupled and uncoupled measures. They suggested that an appreciation of both calculations is necessary and that neither method has received sufficient investigation to provide a superior measure of injury risk.

Practitioners involved in the monitoring of athlete workloads need to be confident that their methodological decisions are based upon the best available evidence. Equally, any criticism of applied training-monitoring strategies should be based upon empirical evidence and practical reality – rather than whether statistical perfection has been achieved within the literature. Our purpose here is to use a real-world dataset to provide novel insights on the differences in injury risk between ACWRs containing either coupled or uncoupled acute and chronic workloads.

Materials and Methods

In a cohort of 28 elite cricket fast bowlers (mean ± SD age, 26 ± 5 yr), we previously demonstrated that coupled ACWRs were associated with injury risk [3]. We have re-examined these data using both coupled and uncoupled ACWR methods. All data were collected according to the principles of the Declaration of Helsinki, in line with the ethical standards for research involving human participants [4, 5].

Quantifying workloads

Workloads were estimated using the session rating of perceived exertion (session-RPE) 10-point category ratio scale [6]. Multiplying the session-RPE and session duration, for either training or competition, provided an estimate of internal workload. The session-RPE has been shown to provide a valid and reliable estimate of intensity [7, 8]. The ratings of perceived exertion were recorded using a pen and paper 30 min after completing the training session or match. Coupled ACWRs were calculated using a 1-week acute workload and 4-week chronic workload (the acute workload was included in the chronic workload calculation), whereas uncoupled ACWRs used the most recent 1-week acute workload and the prior 3-week chronic workload (the acute workload was not included in the chronic workload calculation) [2].

Definition of injury

Injury records were updated and maintained by medical staff from the New South Wales and Victorian Cricket Associations. An injury was defined as any non-contact injury that resulted in a loss of either match-time or greater than one training session over a 1-week period [3].

Statistical analysis

Injury risks were calculated as the number of injuries sustained relative to the number of exposures to each workload category. Binary logistic regression was used to model the univariate association between coupled/uncoupled ACWRs and injury in the subsequent week [3]. Relative risks (RRs) and 95 % confidence intervals (CIs) were calculated to determine which ACWR categories were associated with an increased or decreased risk. Statistical significance was set at $p < 0.05$.

Results

Is there a difference in injury risk between coupled and uncoupled ACWRs?

A nearly perfect second-order polynomial relationship ($R^2 = 0.99$) was found between coupled and uncoupled ACWRs (▶ **Fig. 1a**).

The regression equation displayed in ▶ **Fig. 1a** was used to convert coupled ACWRs into uncoupled data in ▶ **Fig. 1b**. The converted uncoupled ACWRs were then compared with traditional coupled ACWR-injury risk relationships (▶ **Fig. 1b**). At ACWRs greater than 1.0, the conversion of coupled to uncoupled ACWRs shifted the ACWR-injury likelihood curve to the right.

When the original ACWR data were used, no significant differences in injury risk were found between the coupled and uncoupled methods for each percentile rank category (▶ **Fig. 1c**).

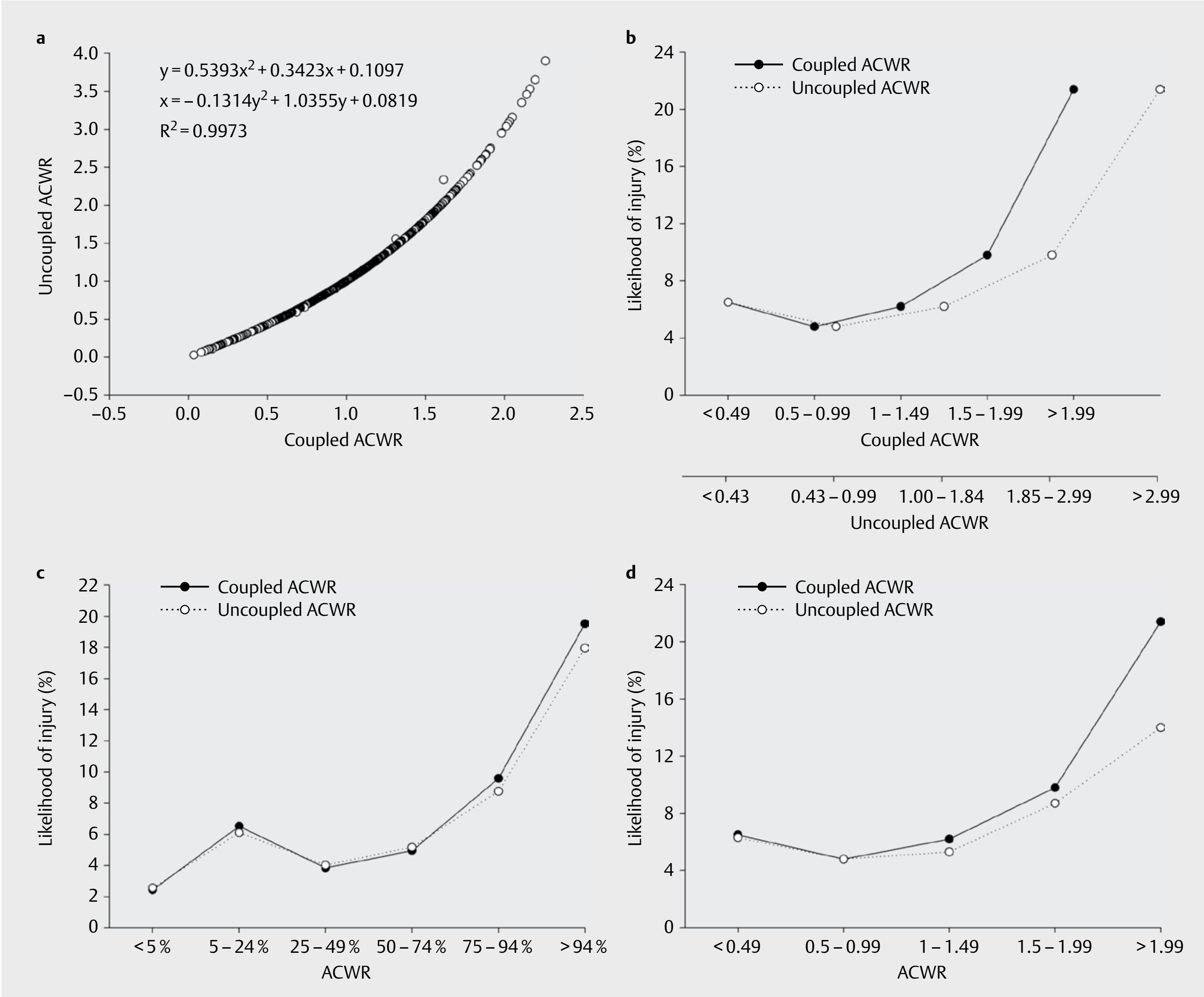
Finally, when the original ACWR data were used, the association between coupled and uncoupled ACWRs and subsequent week injury risk was assessed using the previously described categories [3]. Higher ACWRs were associated with increased injury likelihood for both coupled and uncoupled methods (▶ **Fig. 1d**), however there were no significant differences in injury risk between the coupled and uncoupled methods in any category.

Discussion

Our data demonstrate that both coupled and uncoupled ACWRs produce the same injury likelihoods. Furthermore, our results are consistent with previous studies: higher ACWRs were associated with greater injury risk [9–13], irrespective of whether acute and chronic workloads were coupled or uncoupled.

These findings confirm the separation between the coupled and uncoupled methods for ACWRs greater than 1.0 [2]. Practitioners using previously suggested ACWR thresholds derived using coupled data (i. e., > 1.5 or > 2.0) to interpret uncoupled ACWRs should consider converting these categories using the equation provided in ▶ **Fig. 1a**. Conversion will provide the same injury likelihood for each discrete category as the traditional coupled method. However, given the insignificant differences in injury risk between coupled and uncoupled methods, practitioners needing to use the previously described coupled thresholds with uncoupled ACWRs can do so because both methods reproduced the previous findings of increased injury risk with higher ACWRs. Although it is acknowledged that there is somewhat more statistical purity in the uncoupled ACWRs, in practice it makes little difference. Our findings may assist organisations and clubs that are using either coupled or uncoupled ACWRs to confidently plan training and competition workloads.

We found no evidence to support the discontinuation of coupled ACWRs in a real-world practical setting. In fact, although examination of the ACWR will continue – and is encouraged – rejecting coupled ACWRs in favour of uncoupled ACWRs on the basis that one provides a more valid assessment of injury risk should be considered premature. Practitioners should continue using their chosen method with confidence. If required, practitioners can convert between methods; however, a consistent analytical approach is encouraged. Ideally, practitioners would create their own injury risk models using categories and data that are relevant for their organisation and sport contexts, which should prove more valuable than injury risk profiles developed from other sports. Researchers and practitioners must make specific note of their methods for future interpretation and replication [2]. Importantly, neither coupled nor uncoupled ACWRs should be used in isolation to prescribe and monitor workloads. Historical (e. g., age and previous training experience) [14, 15], physical (e. g., aerobic fitness, lower-body strength and speed) [15–17], environmental and psychosocial factors [18–21] may independently effect injury risk and moderate the workload-injury relationship. As such, interpreting and acting upon ACWR data should be conducted in association with other



▶ **Fig. 1** Relationship between coupled and uncoupled acute:chronic workload ratios (ACWRs), and likelihood of injury with coupled and uncoupled ACWRs. **a** – Relationship between coupled and uncoupled ACWRs; **b** – Likelihood of injury with traditional coupled ACWR and converted uncoupled ACWR data; **c** – Likelihood of injury with the original coupled and uncoupled ACWR data using the percentile rank method; **d** – Likelihood of injury with the original coupled and uncoupled ACWR data using distinct ACWR categories.

important information (i. e., athlete wellness, readiness measures, and risk profile) [22, 23].

Like many studies, our findings are not without their limitations. Others have cautioned against the use of discretisation methods for injury prediction [24]; although our results demonstrate an association between the ACWR and injury likelihood, our findings do not imply that injuries can be predicted from a single training variable. Equally, others have used different acute and chronic loading windows [25, 26] and exponentially weighted moving averages to develop acute and chronic workloads [27]. As such, the novel insights presented here do not answer every question in relation to workload-injury relationships. Further research is clearly required to identify the workload-injury profiles of different tissue types (e. g., bone, tendon, joint, and muscle), if acute and chronic workloads and the ACWR are associated with performance, and whether training loads derived via exponentially weighted moving averages provide a better association with performance than those derived from rolling averages. However, our findings offer valuable information for practitioners working in professional sport – spikes in workload are associated with increased injury risk, regardless of whether acute and chronic workloads are coupled or uncoupled.

In conclusion, the original concept of the ACWR suggests that if an athlete has performed more training than they are prepared for, they are at greater risk of injury [3, 28, 29]. However, this concept has been clouded by methodological debate [1, 2]. Although this debate is welcome and encouraged, it is not an argument against the above-mentioned premise. We suggest that future methodological discussion be supported by real-world data. If the debate counters the hypothesis that athletes performing more training than they are prepared for is not related to future injury, then this should be clearly stated and substantiated.

Conflict of Interest

TJG works as a consultant to several high-performance organisations, including sporting teams, industry, military and higher education institutions. At the time of data collection, PB was employed by Cricket Australia. The remaining authors have no potential conflicts of interest. No funding or grants from any public, commercial, or not-for-profit organisations were used in the preparation of this manuscript.

References

[1] Lolli L, Batterham AM, Hawkins R, Kelly DM, Strudwick AJ, Thorpe R, Gregson W, Atkinson G. Mathematical coupling causes spurious correlation within the conventional acute-to-chronic workload ratio calculations. Br J Sports Med 2017, Nov 3. pii: bjsports-2017-098110. doi:10.1136/bjsports-2017-098110. [Epub ahead of print]

[2] Windt J, Gabbett TJ. Is it all for naught? What does mathematical coupling mean for acute:chronic workload ratios? Br J Sports Med 2018, May 28. pii: bjsports-2017-098925. doi:10.1136/bjs-ports-2017-098925. [Epub ahead of print]

[3] Hulin BT, Gabbett TJ, Blanch P, Chapman P, Bailey D, Orchard JW. Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. Br J Sports Med 2014; 48: 708–712

[4] World Medical Association. Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA 2013; 310: 2191–2194

[5] Harriss DJ, Macsween A, Atkinson G. Standards for ethics in sport and exercise science research: 2018 update. Int J Sports Med 2017; 38: 1126–1131

[6] Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. J Strength Cond Res 2001; 15: 109–115

[7] Foster C. Monitoring training in athletes with special reference to overtraining syndrome. Med Sci Sports Exerc 1998; 30: 1164–1168

[8] Haddad M, Stylianides G, Djaoui L, Dellal A, Chamari K. Session-RPE method for training load monitoring: Validity, ecological usefulness, and influencing factors. Front Neurosci 2017; 11: 1–14

[9] Bowen L, Gross AS, Gimpel M, Bruce-Low S, Li FX. Spikes in acute:chronic workload ratio (ACWR) associated with a 5–7 times greater injury rate in English Premier League football players: A comprehensive 3-year study. Br J Sports Med 2019, Feb 21. pii: bjsports-2018-099422. doi:10.1136/bjsports-2018-099422. [Epub ahead of print]

[10] Bowen L, Gross AS, Gimpel M, Li FX. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. Br J Sports Med 2017; 51: 452–459

[11] Hulin BT, Gabbett TJ, Caputi P, Lawson DW, Sampson JA. Low chronic workload and the acute: chronic workload ratio are more predictive of injury than between-match recovery time: A two-season prospective cohort study in elite rugby league players. Br J Sports Med 2016; 50: 1008–1012

[12] Jaspers A, Kuyvenhoven JP, Staes F, Frencken WGP, Helsen WF, Brink MS. Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. J Sci Med Sport 2018; 21: 579–585

[13] Malone S, Owen A, Newton M, Mendes B, Collins K, Gabbett TJ. The acute:chronic workload ratio in relation to injury risk in professional soccer. J Sci Med Sport 2017; 20: 561–565

[14] Malone S, Roe M, Doran DA, Gabbett TJ, Collins K. High chronic training loads and exposure to bouts of maximal velocity running reduce injury risk in elite Gaelic football. J Sci Med Sport 2017; 20: 250–254

[15] Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. High-speed running and sprinting as an injury risk factor in football: Do well-developed physical qualities reduce the risk? J Sci Med Sport 2018; 21: 257–262

[16] Malone S, Roe M, Doran A, Gabbett TJ, Collins KD. Protection against spikes in workload with aerobic fitness and playing experience: The role of the acute:chronic workload ratio on injury risk in elite Gaelic football. Int J Sports Physiol Perform 2017; 12: 393–401

[17] Malone S, Hughes B, Doran DA, Collins K, Gabbett TJ. Can the workload-injury relationship be moderated by improved strength, speed and repeated-sprint qualities? J Sci Med Sport 2019; 22: 29–34

[18] Ivarrson A, Johnson U, Andersen MB, Tranaeus U, Stenling A, Lindwall M. Psychosocial factors and sports injuries: Meta-analyses for prediction and prevention. Sports Med 2017; 47: 353–365

[19] Mann JB, Bryant KR, Johnstone B, Ivey PA, Sayers SP. Effect of physical and academic stress on illness and injury in division 1 college football players. J Strength Cond Res 2016; 30: 20–25

[20] Milewski MD, Skaggs DL, Bishop GA, Pace JL, Ibrahim DA, Wren TA, Barzdukas A. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. J Petriatr Orthop 2014; 34: 129–133

[21] von Rosen P, Frohm A, Kottorp A, Friden C, Heijne A. Multiple factors explain injury risk in adolescent athletes: Applying a biopsychosocial perspective. Scand J Med Sci Sports 2017; 27: 2059–2069

[22] Gabbett TJ. Debunking the myths about training load, injury and performance: Empirical evidence, hot topics and recommendations for practitioners. Br J Sports Med 2018, Oct 26. pii: bjs-ports-2018-099784. doi:10.1136/bjsports-2018-099784. [Epub ahead of print]

[23] Hulin BT, Gabbett TJ. Indeed association does not equal prediction: The never-ending search for the perfect acute:chronic workload ratio. Br J Sports Med 2019; 53: 144–145

[24] Carey DA, Crossely KM, Whitely R, Mosler A, Ong KL, Crow J, Morris ME. Modelling training loads and injuries: The dangers of discretization. Med Sci Sports Exerc 2018; 50: 2267–2276

[25] Carey DL, Blanch P, Ong KL, Crossley KM, Crow J, Morris ME. Training loads and injury risk in Australian football-differing acute:chronic workload ratios influence match injury risk. Br J Sports Med 2017; 51: 1215–1220

[26] Stares J, Dawson B, Peeling P, Heasman J, Rogalski B, Drew M, Colby M, Dupont G, Lester L. Identifying high risk loading conditions for in-season injury in elite Australian football players. J Sci Med Sport 2018; 21: 46–51

[27] Williams S, West S, Cross MJ, Stokes KA. Better way to determine the acute:chronic workload ratio? Br J Sports Med 2017; 51: 209–210

[28] Gabbett TJ, Hulin BT, Blanch P, Whiteley R. High training loads alone do not cause sports injuries: How you get there is the real issue. Br J Sports Med 2016; 50: 444–445

[29] Gabbett TJ. The training—injury prevention paradox: Should athletes be training smarter and harder? Br J Sports Med 2016; 50: 273–280