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Injury Predictability of Acute:Chronic Workload Ratios: A Systematic Review and Meta-Analysis

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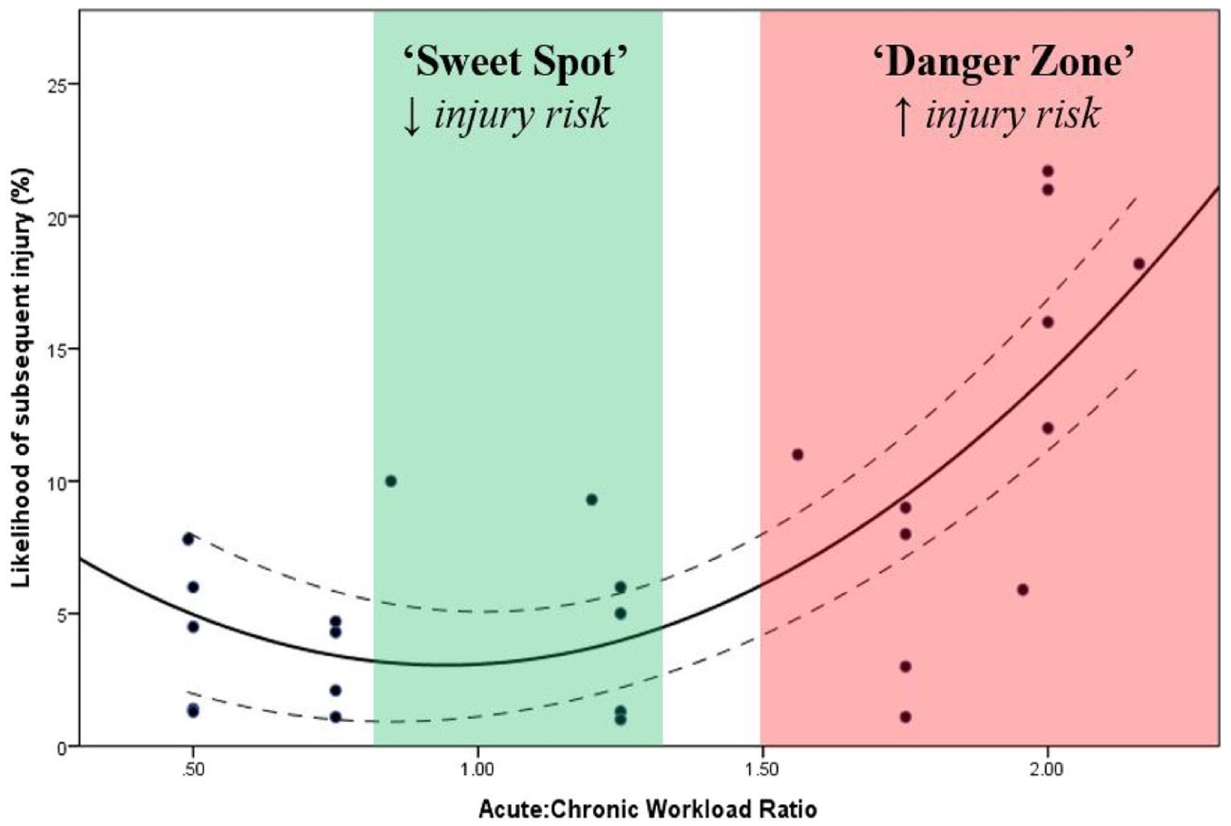
Introduction

- Low injury rates have previously been correlated with sporting team success[1], highlighting the importance of injury mitigation programs.
- The use of monitoring and optimizing training load has increased in elite sport as an effective tool to reduce injury risk while ensuring improvements in fitness.
- One particular method, Acute:Chronic Workload Ratios (ACWR), has been used to monitor an athlete's level of preparedness[2]. ACWR can be calculated via a rolling average of exponentially weighted moving averages (EWMA)[3].
- It has previously, been theorized that ratios between 0.80-1.30 will provide the lowest risk of injury[2]. (Figure 1) While this number has been supported by individual studies[4,5], no evaluation of the literature as a whole has yet been performed.

Figure 1: ACWR and Injury Risk Reproduced from Tim Gabbett[2]



Purpose

- The aim of this systematic review was to identify, critically appraise, and synthesize key findings in the literature regarding ACWR to determine if a relationship exists with musculoskeletal injury risk in sports and, if so, which ratios may result in the lowest risk of injury.

Methods

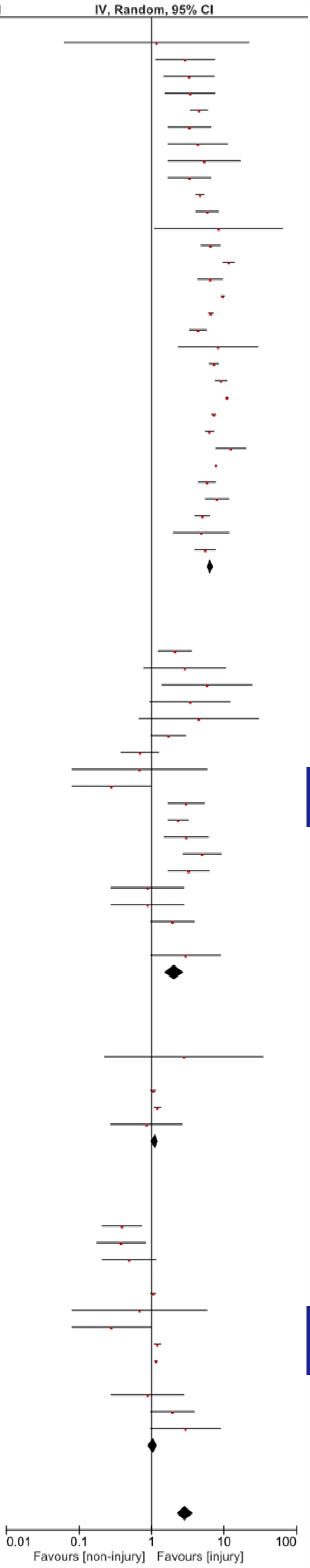
- Pubmed, Embase, CINAHL, and Sports Discuss databases were searched using key search terms, developed through a preliminary review of the literature and using subject matter experts.
- Duplicates were removed, and articles were screened using inclusion and exclusion criteria established prior to screening.
- The Downs and Black checklist was used to critically appraise included studies and provide a strength of evidence for this method of injury risk prediction.
- A Kappa analysis was performed to investigate the level of agreement between raters (DM & BS) with the final score settled by consensus (RO).
- The scoring system proposed by Kennelly was used to grade the final score. Relevant data were extracted, tabulated, and synthesized.

Results

- Almost perfect interrater agreement (κ = 0.954) existed between raters on the Downs and Black.
- There was a high variety between studies with different variables studied (total distance versus high speed running), as well as differences between ratios analyzed (1.50-1.80 versus ≥1.50), and reference groups (0.80 to 1.20 versus ≤0.85). (Figure 2)
- Considering this variability, it does appear that utilizing ACWR for external (e.g. total distance) and internal (e.g. heart rate) loads could be effective for predicting injury risk.
- Calculating ACWR via EWMA may potentially result in a more sensitive measure of injury risk.
- There also appears to be a trend towards the ratios of 0.8 to 1.3 demonstrating the lowest risk of injury.

Figure 2: ACWR Injury Predictability Forest Plot

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
1.8.1 ACWR >2.0				
Harrison sRPE	0.157	1.4953	0.5%	1.17 [0.06, 21.93]
Hulin (b) Bowls 49%*	1.0647	0.4764	1.5%	2.90 [1.14, 7.38]
Hulin (b) Bowls 50-99%*	1.1939	0.4023	1.6%	3.30 [1.50, 7.26]
Hulin (b) sRPE 49%*	1.2238	0.3975	1.6%	3.40 [1.56, 7.41]
Hulin (b) sRPE 50-99%*	1.5041	0.1385	1.8%	4.50 [3.43, 5.90]
Malone 2017 sRPEa	1.203	0.346	1.6%	3.33 [1.69, 6.56]
Malone 2017 sRPEb	1.4656	0.48	1.5%	4.33 [1.69, 11.09]
Malone 2017 sRPEc	1.6734	0.586	1.3%	5.33 [1.69, 16.81]
Malone 2017 sRPEd	1.203	0.346	1.6%	3.33 [1.69, 6.56]
Murray (a) HSR*	1.539	0.0628	1.9%	4.66 [4.12, 5.27]
Murray (a) PL*	1.7699	0.1806	1.8%	5.87 [4.12, 8.36]
Murray (a) TD1*	2.1294	1.0425	0.8%	8.41 [1.09, 64.89]
Murray (a) TD2*	1.8749	0.1531	1.8%	6.52 [4.83, 8.80]
Murray (b) HSR1*	2.4527	0.0889	1.8%	11.62 [9.76, 13.83]
Murray (b) HSR2*	1.8656	0.2025	1.8%	6.46 [4.34, 9.61]
Murray (b) HSR3*	2.2649	0.0271	1.9%	9.63 [9.13, 10.16]
Murray (b) HSR4*	1.8779	0.0334	1.9%	6.54 [6.13, 6.98]
Murray (b) HSR5*	1.4725	0.1336	1.8%	4.36 [3.36, 5.67]
Murray (b) LSR1*	2.115	0.6386	1.3%	8.29 [2.37, 28.98]
Murray (b) LSR2*	1.981	0.072	1.9%	7.25 [6.30, 8.35]
Murray (b) LSR3*	2.2039	0.0926	1.8%	9.06 [7.56, 10.86]
Murray (b) MSR1*	2.3961	0.014	1.9%	10.98 [10.68, 11.29]
Murray (b) MSR2*	1.9755	0.0299	1.9%	7.21 [6.80, 7.65]
Murray (b) PL1*	1.8358	0.0665	1.9%	6.27 [5.50, 7.14]
Murray (b) PL2*	2.5225	0.2433	1.7%	12.46 [7.73, 20.07]
Murray (b) PL3*	2.0438	0.0119	1.9%	7.72 [7.54, 7.90]
Murray (b) PL4*	1.7579	0.1383	1.8%	5.80 [4.42, 7.61]
Murray (b) TD1*	2.0769	0.1877	1.8%	7.98 [5.52, 11.53]
Murray (b) TD2*	1.6174	0.1167	1.8%	5.04 [4.01, 6.34]
Murray (b) TD3*	1.5831	0.4482	1.5%	4.87 [2.02, 11.72]
Murray (b) TD4*	1.7029	0.1643	1.8%	5.49 [3.98, 7.58]
Subtotal (95% CI)			**51.5%**	**6.49 [5.80, 7.26]**
Heterogeneity: Tau² = 0.06; Chi² = 772.17, df = 30 (P < 0.00001); I² = 96%				
Test for overall effect: Z = 32.74 (P < 0.00001)				
1.8.2 ACWR 1.00-2.00				
Hulin (a) sRPE 1.00-2.00*	0.7419	0.2647	1.7%	2.10 [1.25, 3.53]
Hulin (b) TD1 1.00-2.00*	1.0578	0.6616	1.2%	2.88 [0.79, 10.53]
Hulin (b) TD2 1.00-2.00*	1.7579	0.7285	1.2%	5.80 [1.39, 24.19]
Hulin (b) TD3 1.00-2.00*	1.2267	0.6503	1.3%	3.41 [0.95, 12.20]
Hulin (b) TD4 1.00-2.00*	1.4951	0.9663	0.9%	4.46 [0.67, 29.64]
Jaspers sRPE1 1.00-2.00	0.5365	0.2794	1.7%	1.71 [0.99, 2.96]
Jaspers sRPE2 1.00-2.00	-0.3711	0.3018	1.7%	0.69 [0.38, 1.25]
Malone (a) sRPE1 1.00-2.00	-0.3857	1.0919	0.8%	0.68 [0.08, 5.78]
Malone (a) sRPE2 1.00-2.00	-1.273	0.6392	1.3%	0.28 [0.08, 0.98]
Malone (a) sRPE3 1.00-2.00	1.0986	0.2928	1.7%	3.00 [1.69, 5.33]
Malone (a) sRPE4 1.00-2.00	0.8459	0.1638	1.8%	2.33 [1.69, 3.21]
Malone (b) HSR 1.00-2.00	1.1053	0.3529	1.6%	3.02 [1.51, 6.03]
Malone (b) SD 1.00-2.00	1.6094	0.3085	1.7%	5.00 [2.73, 9.15]
Malone (c) sRPE1 1.00-2.00	1.1787	0.3336	1.7%	3.25 [1.69, 6.25]
Malone (c) sRPE2 1.00-2.00	-0.1278	0.5843	1.3%	0.88 [0.28, 2.77]
Malone (c) sRPE3 1.00-2.00	-0.1278	0.5843	1.3%	0.88 [0.28, 2.77]
Malone (c) sRPE4 1.00-2.00	0.6678	0.351	1.6%	1.95 [0.98, 3.88]
Malone (c) sRPE5 1.00-2.00	0	0		Not estimable
Malone (c) sRPE6 1.00-2.00	1.0818	0.5623	1.4%	2.95 [0.98, 8.88]
Subtotal (95% CI)			**26.0%**	**2.05 [1.51, 2.78]**
Heterogeneity: Tau² = 0.23; Chi² = 45.82, df = 17 (P = 0.0002); I² = 63%				
Test for overall effect: Z = 4.61 (P < 0.00001)				
1.8.3 ACWR <1.00				
Harrsion sRPE 0.0-1.0	1.0296	1.2818	0.7%	2.80 [0.23, 34.53]
Malone (a) sRPE 0.0-1.00	0	0		Not estimable
Malone (a) sRPE2 0.0-1.00	0.0488	0.0352	1.9%	1.05 [0.98, 1.13]
Malone (b) HSR 0.0-1.00	0.1823	0.0529	1.9%	1.20 [1.08, 1.33]
Malone (b) SD 0.0-1.00	-0.1625	0.5752	1.4%	0.85 [0.28, 2.62]
Subtotal (95% CI)			**5.7%**	**1.11 [1.00, 1.24]**
Heterogeneity: Tau² = 0.00; Chi² = 5.14, df = 3 (P = 0.16); I² = 42%				
Test for overall effect: Z = 1.92 (P = 0.05)				
1.8.4 ACWR 0.8-1.3				
Jaspers ACC 0.8-1.3	-0.9416	0.321	1.7%	0.39 [0.21, 0.73]
Jaspers DEC 0.8-1.3	-0.9676	0.3902	1.6%	0.38 [0.18, 0.82]
Jaspers sRPE 0.8-1.3	-0.7133	0.4339	1.5%	0.49 [0.21, 1.15]
Malone (a) sRPE1 0.8-1.3	0	0		Not estimable
Malone (a) sRPE2 0.8-1.3	0.0488	0.0352	1.9%	1.05 [0.98, 1.13]
Malone (a) sRPE3 0.8-1.3	-0.3857	1.0919	0.8%	0.68 [0.08, 5.78]
Malone (a) sRPE4 0.8-1.3	-1.273	0.6392	1.3%	0.28 [0.08, 0.98]
Malone (b) HSR 0.8-1.3	0.1823	0.0529	1.9%	1.20 [1.08, 1.33]
Malone (b) SD 1 0.8-1.3	0.1398	0.0215	1.9%	1.15 [1.10, 1.20]
Malone (c) sRPE1 0.8-1.3	0	0		Not estimable
Malone (c) sRPE2 0.8-1.3	-0.1278	0.5843	1.3%	0.88 [0.28, 2.77]
Malone (c) sRPE3 0.8-1.3	0.6678	0.351	1.6%	1.95 [0.98, 3.88]
Malone (c) sRPE4 0.8-1.3	1.0818	0.5623	1.4%	2.95 [0.98, 8.88]
Subtotal (95% CI)			**16.8%**	**1.04 [0.90, 1.19]**
Heterogeneity: Tau² = 0.02; Chi² = 39.19, df = 10 (P < 0.0001); I² = 74%				
Test for overall effect: Z = 0.53 (P = 0.60)				
Total (95% CI)			**100.0%**	**2.93 [2.28, 3.77]**
Heterogeneity: Tau² = 0.89; Chi² = 15700.63, df = 63 (P < 0.00001); I² = 100%				
Test for overall effect: Z = 8.35 (P < 0.00001)				
Test for subgroup differences: Chi² = 621.42, df = 3 (P < 0.00001), I² = 99.5%				



sRPE: session Rating of Perceived Exertion, HSR: High Speed Running, PL: Player Load, TD: Total Distance, LSR: Low Speed Running, MSR: Medium Speed Running, SD: Sprint Distance, ACC: Acceleration Effort, DEC: Deceleration effort

Discussion and Conclusion

- This research supports ACWR as a tool to predict injury risk, while the utilization of EWMA may be a more sensitive measure.
- Ratios between 0.80 to 1.30 appear to result in the lowest injury risk. Sporting clinicians may wish to utilize higher loads for greater increases in fitness, though this review did not examine ACWR and its effect on fitness.

Recommendations

- Further research should attempt to use more standardized measures to allow for more objective results, though this will always be impacted by differences in sports.
- Further research on the effects of ACWR on fitness is needed to further guide clinicians.
- Utilizing ACWR is an effective tool to predict injury risk, but other methods of monitoring training load should not be ignored.

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