RELATIONSHIP BETWEEN RUNNING LOADS AND SOFT-TISSUE INJURY IN ELITE TEAM SPORT ATHLETES

TIM J. GABBETT[1,2] AND SHAHID ULLAH[3]

[1]*School of Exercise Science, Australian Catholic University, Queensland, Australia;* [2]*School of Human Movement Studies, The University of Queensland, Queensland, Australia; and* [3]*School of Human Movement and Sport Sciences, University of Ballarat, Victoria, Australia*

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ABSTRACT

Gabbett, TJ and Ullah, S. Relationship between running loads and soft-tissue injury in elite team sport athletes. *J Strength Cond Res* 26(4): 953–960, 2012—Although the potential link between running loads and soft-tissue injury is appealing, the evidence supporting or refuting this relationship in high-performance team sport athletes is nonexistent, with all published studies using subjective measures (e.g., ratings of perceived exertion) to quantify training loads. The purpose of this study was to investigate the risk of low-intensity (e.g., walking, jogging, total distances) and high-intensity (e.g., high acceleration and velocity efforts, repeated high-intensity exercise bouts) movement activities on lower body soft-tissue injury in elite team sport athletes. Thirty-four elite rugby league players participated in this study. Global positioning system data and the incidence of lower body soft-tissue injuries were monitored in 117 skill training sessions during the preseason and in-season periods. The frailty model (an extension of the Cox proportional regression model for recurrent events) was applied to calculate the relative risk of injury after controlling for all other training data. The risk of injury was 2.7 (95% confidence interval 1.2–6.5) times higher when very high–velocity running (i.e., sprinting) exceeded 9 m per session. Greater distances covered in mild, moderate, and maximum accelerations and low- and very low–intensity movement velocities were associated with a reduced risk of injury. These results demonstrate that greater amounts of very high–velocity running (i.e., sprinting) are associated with an increased risk of lower body soft-tissue injury, whereas distances covered at low and moderate speeds offer a protective effect against soft-tissue injury. From an injury prevention perspective, these findings provide empirical support for restricting the amount of sprinting performed in preparation for elite team sport competition. However, coaches should also consider the consequences of reducing training loads on the development of physical qualities and playing performance.

KEY WORDS injury risk, running loads, global positioning system, rugby league, injury prevention

INTRODUCTION

The training-performance relationship is of particular importance to coaches to determine the optimum amount of training required to attain specific performance levels (4,11). Bannister et al. (6–8) proposed a statistical model to describe an athlete's response to a given training stimulus. According to this model, the performance of an athlete in response to training can be estimated from the difference between a negative function (fatigue) and a positive function (fitness). Studies have described the training-performance relationship as analogous with the dose-response relationship reported in pharmacological studies, with the primary goal of providing a training stimulus that maximizes performance potential and minimizes the negative consequences of training (i.e., injury, illness, fatigue, overtraining) (26).

Several studies have investigated the influence of training volume, intensity, and frequency on athletic performance, with performance generally improving with increases in training load (11,32). Studies of the training-performance relationship in individual sports (e.g., swimming and running) have found a positive relationship between both greater training volume and performance (12) and higher training intensity and performance (27). Foster et al. (11) studied 56 runners, cyclists, and speed skaters during 12 weeks of training and reported that a 10-fold increase in training load was associated with an approximately 10% improvement in performance. Moreover, Stewart and Hopkins (32) reported a significant relationship between greater training volume and performance ($r = 0.50–0.80$) and higher training intensity and performance ($r = 0.60–0.70$) in competitive swimmers. However, it has also been shown that negative adaptations to exercise training are dose related, with the highest incidence of illness and injury occurring when training loads are highest (10,15). In a recent study of Ironman distance triathletes,

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Address correspondence to Tim Gabbett, tim_gabbett@yahoo.com.au.

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Vleck et al. (34) demonstrated a significant relationship between the amount of intensive training sessions performed and the incidence of overuse injury. These findings have been confirmed in studies of international rowers (35) and military personnel (29); higher training loads and running volumes were associated with higher injury rates. A limitation of all of these studies is that training intensities were subjectively determined, and total weekly volumes were not partitioned into the amount of running performed at low and high intensities.

In contrast to most individual sports, team sports (e.g., ice hockey, rugby, soccer, basketball, and lacrosse) are often characterized by short repeated sprints, rapid acceleration, deceleration, and changes of direction and an ability to produce high levels of muscular force extremely rapidly (17,31). As a result, team sport athletes are required to have well-developed speed, strength, muscular power, agility, and maximal aerobic power ($\dot{V}O_2$max). Previous studies of team sport athletes have reported significant positive relationships between training loads and training-injury rates (15,21), suggesting that the harder these athletes train, the more injuries they will sustain. Furthermore, reductions in training loads have been shown to reduce training-injury rates and result in greater improvements in $\dot{V}O_2$max (14). In a squad of high-performance basketball players, Anderson et al. (1) reported a significant relationship ($r = 0.68$) between training load and injury, suggesting that the periodization pattern of basketball training may be linked to the likelihood of injury. However, it has also been shown that team sport athletes who perform <18 weeks of preseason training before sustaining an initial injury are at increased risk of sustaining a subsequent injury, whereas players with a low off-season $\dot{V}O_2$max are at increased risk of sustaining an injury (19). Clearly, training for team sports reflects a balance between the minimum training load required to elicit an improvement in fitness and the maximum training load tolerable before sustaining marked increases in injury rates.

A considerable proportion of injuries sustained by team sport athletes are noncontact, soft-tissue issues that occur as a result of excessive training loads, inadequate recovery, and overtraining (13,16,20). These injuries, which are largely preventable, have the potential to impact on team selections and as a result may influence team performance. As team sport athletes use a combination of traditional conditioning, skills 'drills,' and small-sided games in training, the quantification of running loads for these athletes has often proved difficult. Until recently, estimates of the physiological demands of training (and competition) activities were dependent on time-consuming and often laborious video tracking technology. With the introduction of microtechnology (e.g., global positioning systems [GPS] and accelerometers) into the high-performance sporting environment, sport scientists are now able to quantify the distance covered in discrete velocity bands, along with short duration, high-acceleration efforts; high-velocity sprints; and repeated high-intensity exercise bouts (18). Furthermore, research from our laboratory (22) has also recently validated this technology to automatically detect other physically demanding activities that regularly occur in team sport activities (e.g., the frequent tackles and collisions that occur in the rugby codes).

This technology has obvious applications for conditioning coaches responsible for designing and delivering periodized training programs; coaches can quickly identify athletes who have performed the 'planned' training load, and those athletes who may be susceptible to injury or illness because of overtraining. Indeed, conditioning coaches often use GPS data to restrict the amount of high-intensity running athletes perform in a given training session or across training sessions. Although the potential link between running loads and soft-tissue injury is appealing, the evidence supporting or refuting this relationship in high-performance team sport athletes is nonexistent, with all published studies using subjective measures (e.g., ratings of perceived exertion) to quantify training loads. With this in mind, the purpose of this study was to document the running loads performed during training in elite team sport athletes. The second purpose was to investigate the relative risk of low-intensity (e.g., walking, jogging, total distances) and high-intensity (e.g., high acceleration and velocity efforts, repeated high-intensity exercise bouts) movement activities on lower body soft-tissue injury in these athletes.

METHODS

Experimental Approach to the Problem

Global positioning system and lower body soft-tissue injury data were prospectively recorded over one season in elite National Rugby League (NRL) players. Data were collected during the preseason and in-season periods. The frailty model (an extension of the Cox proportional regression model for recurrent events) (25) was applied to calculate the relative risk of injury after adjusting for all other training data. It was hypothesized that higher total running volumes and greater amounts of very high-velocity running (i.e., sprinting) would be associated with an increased risk of lower body soft-tissue injury.

Subjects

Thirty-four elite team sport athletes (mean ± *SD* age, 23.6 ± 3.8 years; playing experience, 55.0 ± 72.2 NRL matches; and $\dot{V}O_2$max, 54.6 ± 2.4 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in this study. All the participants were highly motivated players from the same professional rugby league club that regularly trained as part of the elite NRL squad. All the players were competing in the NRL competition and were free from injury at the commencement of the study. Along with the British Super League, the NRL is considered to be of the highest standard of rugby league competition in the world. All the participants received a clear explanation of the study, and written consent was obtained. The Institution Ethics Committee for Human Investigation approved all experimental procedures.

Movement was recorded by a GPS unit (MinimaxX, Catapult Innovations, Melbourne, Australia) sampling at 5 Hz. The GPS signal provided information on speed, distance, position, and

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TABLE 1. Running loads of professional rugby league players during the preseason, early-competition, and late-competition phases of the season.

	Preseason		Early competition		Late competition	
	Mean (range)	*SE*	Mean (range)	*SE*	Mean (range)	*SE*
Total distance (m)	4,002.6 (971.0–6,750.0)	65.8	3,923.3 (609.0–11,058.0)	76.2	3,448.8 (1,219.0–6,592.0)	64.9
Relative distance ($m \cdot min^{-1}$)	69.6 (34.6–177.0)	1.8	62.6 (27.6–146.0)	0.8	67.5 (33.7–147.5)	1.1
Very-low intensity (m)	577.6 (13.0–1,888.0)	14.8	566.5 (35.0–1,711.0)	13.4	441.6 (31.0–930.0)	10.9
Low intensity (m)	2,417.5 (402.0–4,163.0)	46.8	2,342.3 (198.0–7,376.0)	47.0	2,038.4 (488.0–3,770.0)	42.2
Moderate intensity (m)	831.3 (111.0–1,714.0)	14.3	812.2 (166.0–2,216.0)	17.2	786.2 (306.0–1,768.0)	16.7
High intensity (m)	181.7 (4.0–520.0)	4.8	186.0 (16.0–641.0)	5.3	188.9 (23.0–684.0)	5.3
Very-high intensity (m)	19.5 (0–134.0)	1.2	13.6 (0–100.0)	1.0	12.2 (0–74.0)	0.9
Total high-speed running (m)	211.4 (4.0–614.0)	5.8	199.3 (16.0–685.0)	5.9	200.4 (23.0–684.0)	5.5
Mild acceleration (m)	199.9 (55.0–379.0)	3.5	204.8 (37.0–583.0)	3.9	152.2 (28.0–412.0)	4.3
Moderate acceleration (m)	229.4 (35.0–488.0)	5.0	249.8 (50.0–663.0)	4.9	133.6 (8.0–463.0)	6.1
Maximum acceleration (m)	141.3 (0–345.0)	4.1	167.7 (26.0–462.0)	3.6	57.0 (0–276.0)	4.6
Repeated high-intensity effort bouts (no.)	4.7 (0.0–15.0)	0.2	7.0 (0.0–19.0)	0.4	2.0 (0.0–9.0)	0.1

*Velocity: very low intensity = 0–1 $m \cdot s^{-1}$; low intensity = 1–3 $m \cdot s^{-1}$; moderate intensity = 3–5 $m \cdot s^{-1}$; high intensity = 5–7 $m \cdot s^{-1}$; very high intensity = >7 $m \cdot s^{-1}$; total high-speed running = all distance covered >5 $m \cdot s^{-1}$; acceleration: mild acceleration = 0.55–1.11 $m \cdot s^{-2}$; moderate acceleration = 1.12–2.78 $m \cdot s^{-2}$; maximum acceleration = ≥ 2.79 $m \cdot s^{-2}$; repeated high-intensity effort bouts: 3 or more maximal acceleration sprint efforts, very high–velocity sprint efforts, and tackle efforts with <21 seconds between efforts; *SE* = standard error.

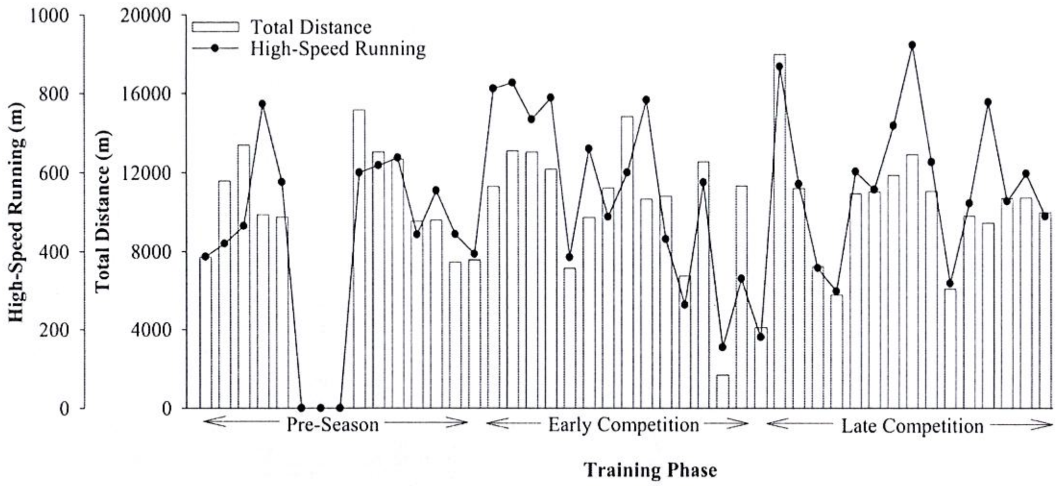

Figure 1. Weekly total training distance, and distance covered in high-speed running over the course of a professional rugby league season. *High-speed running includes all distances covered >5 m·s^{-1}.

and gyroscopes sampling at 100 Hz, to provide greater accuracy on speed and acceleration and information on physical contact and repeated high-intensity efforts (RHIEs). The unit was worn in a small vest, on the upper back of the players.

Data were categorized into (a) discrete acceleration bands, corresponding to mild (0.55–1.11 m·s^{-2}), moderate (1.12–2.78 m·s^{-2}), and maximal (≥2.79 m·s^{-2}) accelerations (2); (b) discrete movement velocity bands, corresponding to very low–intensity (0–1 m·s^{-1}), low-intensity (1–3 m·s^{-1}), moderate-intensity (3–5 m·s^{-1}), high-intensity (5–7 m·s^{-1}), and very high–intensity (>7 m·s^{-1}) velocities (9); and (c) RHIE bouts (18). An RHIE bout was defined as 3 or more high-acceleration, high-velocity, or contact efforts with <21 seconds recovery between efforts (3,18). Several authors have found the accuracy of GPS technology for measuring the movement of athletes to be very good, including Townshend et al. (33) who reported that 90.8% of GPS velocity measurements were <0.1 m·s^{-1} from actual velocity and that the mean distance error was 1.1 ± 0.3 m. The GPS units used in this study have been shown to have acceptable reliability and validity for estimating total distances and total distance covered at high intensities (28), whereas the accelerometers and gyroscopes embedded in the units have also been shown to offer a valid measurement of tackles and repeated efforts commonly observed in collision sports (22).

The GPS data and the incidence of lower body soft-tissue injuries were monitored over one NRL season. Data were collected from 117 skills training sessions during the preseason and in-season periods. The season lasted from November through September. Each player participated in up to 5 skills or conditioning sessions per week. The players

Table 2. Injury incidence by different playing positions in professional rugby league players.

		Transient		Time loss		Missed matches	
Positional group	Exposure (h)	Number	Rate (95% CI)	Number	Rate (95% CI)	Number	Rate (95% CI)
Hit-up forwards	320.3	11	34.3 (17.1–61.4)	12	37.5 (19.4–65.4))	2	6.2 (0.8–22.6)
Wide running forwards	258.8	21	81.2 (50.2–124.0)	7	27.1 (10.9–55.7)	1	3.9 (0.1–21.5)
Adjustables	308.7	2	6.5 (0.8–23.4)	15	48.6 (27.2–80.1)	5	16.2 (5.3–37.8)
Outside backs	181.0	6	33.1 (12.2–72.2)	13	71.8 (38.2–122.8	6	33.1 (12.2–72.2)

*CI = confidence interval.

†All injuries were classified as a transient (no training missed), time loss (any injury resulting in missed training), or a missed match (any injury resulting in a subsequent missed match) injury. Rates are reported per 1,000 training hours (and 95% CI).

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TABLE 3. Potential risk factors for soft-tissue training injuries in professional rugby league players.

Risk factors		Injury incidence (95% CI)		
		Transient	Time loss	Missed matches
Injury history in the previous season	No	36.7 (21.7–57.9)	42.8 (26.5–65.4)	12.2 (4.5–26.6)
	Yes	38.1 (23.9–57.6)	45.0 (29.4–65.9)	13.8 (6.0–27.3)
Total distance	≤3,910 m	57.4 (36.0–87.0)	67.9 (44.3–99.5)	18.3 (7.3–37.0)
	>3,910 m	26.2 (15.6–41.5)	30.6 (19.0–46.8)	10.2 (4.1–21.0)
Relative distance	≤60 $m\cdot min^{-1}$	36.4 (22.8–55.0)	44.6 (29.4–64.9)	13.2 (5.7–26.1)
	>60 $m\cdot min^{-1}$	39.1 (23.2–61.8)	43.5 (26.6–67.1)	13.0 (4.8–28.3)
Very-low intensity	≤542 m	57.5 (36.0–87.0)	65.3 (42.3–96.4)	18.3 (7.4–37.7)
	>542 m	26.5 (15.7–41.9)	32.4 (20.3–49.1)	10.3 (4.1–21.2)
Low intensity	≤2,342 m	57.6 (36.1–87.2)	70.7 (46.6–102.9)‡	18.3 (7.4–37.8)
	>2,342 m	26.5 (15.7–41.9)	29.5 (18.0–45.5)	10.3 (4.1–21.3)
Moderate intensity	≤782 m	60.8 (39.7–89.1)‡	63.1 (41.6–91.9)	23.4 (11.2–43.0)
	>782 m	22.1 (12.1–37.1)	31.5 (19.3–48.7)	6.3 (1.7–16.2)
High intensity	≤175 m	42.2 (26.1–64.5)	48.2 (30.9–71.8)	14.1 (5.7–29.0)
	>175 m	33.7 (20.3–52.6)	40.8 (25.8–61.2)	12.4 (5.0–25.6)
Very-high intensity	≤9 m	31.2 (18.2–50.0)	47.8 (31.2–70.0)	12.9 (5.2–26.5)
	>9 m	44.5 (28.2–66.7)	40.6 (25.1–62.1)	13.5 (5.4–27.9)
Total high intensity	≤190 m	39.1 (23.9–60.4)	43.0 (27.0–65.1)	13.7 (5.5–28.1)
	>190 m	35.9 (21.9–55.4)	44.9 (29.0–66.2)	12.6 (5.0–25.9)
Mild acceleration	≤186 m	70.4 (47.1–101.1)‡	67.9 (45.1–98.2)‡	17.0 (6.8–35.0)
	>186 m	16.9 (8.5–30.3)	29.3 (17.6–45.7)	10.8 (4.3–22.2)
Moderate acceleration	≤217 m	65.3 (43.0–95.0)‡	70.1 (47.0–100.7)‡	16.9 (6.8–34.9)
	>217 m	20.1 (10.7–34.3)	27.8 (16.5–43.9)	10.8 (4.3–22.2)
Maximum acceleration	≤143 m	61.6 (39.9–91.0)‡	69.0 (45.9–99.7)‡	14.8 (5.4–32.2)
	>143 m	22.9 (12.8–37.8)	29.0 (17.5–45.3)	12.2 (5.3–24.1)
Repeated high-intensity effort bouts (no.)	≤3	46.3 (26.5–75.2)	46.3 (26.5–75.2)	14.5 (4.7–33.8)
	>3	35.5 (20.3–57.6)	55.4 (35.9–81.8)	11.1 (3.6–25.9)

*CI = confidence interval.

†All injuries were classified as a transient (no training missed), time loss (any injury resulting in missed training), or a missed match (any injury resulting in a subsequent missed match) injury. Rates are reported per 1,000 training hours (and 95% CI).

‡$p < 0.01$.

were assigned to 1 of 4 positional groups; training for these groups differed relative to specific on-field skills and physiological demands. The 4 groups included hit-up forwards (props), wide running forwards (second row and locks), adjustables (hookers, halfbacks, five-eighths, and fullbacks), and outside backs (centers and wing). The players were allocated into the positional group at the beginning of the season and remained in that training group for the duration of the season. Skill sessions were designed to develop passing and catching skills, tackling technique, support play, defensive line speed and shape, and ball control. Although some differences existed in the intensity of activities performed throughout the season, the types of activities performed in the preseason training phase were similar to those in the early-competition and late-competition training phases. The duration of training sessions was typically between 60 and 100 minutes.

An injury was defined as any noncontact, lower body soft-tissue injury suffered by a player during a training session. The soft-tissue injuries in this study included muscular strains, tears, and tendon injuries. All the injuries were diagnosed by the club physiotherapist and were classified as a transient (no training missed), time loss (any injury resulting in missed training) (22), or a missed match (any injury resulting in a subsequent missed match) injury (23,24). Injury was verified by the presence of one of more of the following characteristics: pain, tenderness, swelling, and restricted range of motion.

Statistical Analyses

Descriptive statistics were expressed as means, ranges, and the standard errors (SEs) of running loads during the preseason, early-competition, and late-competition phases of the season. Injury incidence was calculated by dividing the total number of injuries by the total number of training hours and expressed as rates per 1,000 hours. The 95% confidence intervals (CIs) were calculated using the Poisson distribution, and the level of significance was set at $p \leq 0.05$. The frailty model (an extension of the Cox proportional regression model for recurrent events) (25) was applied to calculate the relative risk of injury after adjusting for all other training data. The SPSS (version 18.0)

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Table 4. Relative risks of potential risk factors for soft-tissue training injuries in professional rugby league players.

Risk factors	Relative risk (95% CI)		
	Transient	Time lost	Missed matches
Injury history in the previous season (no vs. yes)	1.4 (0.6–2.8)	0.7 (0.4–1.4)	0.9 (0.2–4.1)
Total distance (≤3,910 vs. >3,910 m)	0.6 (0.3–1.4)	0.5 (0.2–1.1)	1.1 (0.2–6.0)
Relative distance (≤60 vs. >60 m·min^{-1})	1.2 (0.5–2.6)	0.8 (0.4–1.6)	0.7 (0.2–2.8)
Very-low intensity (≤542 vs. >542 m)	0.6 (0.2–1.3)	0.4 (0.2–0.9)†	0.4 (0.1–2.8)
Low intensity (≤2,342 vs. >2,342 m)	0.5 (0.2–1.1)	0.5 (0.2–0.9)†	1.2 (0.2–5.5)
Moderate intensity (≤782 vs. >782 m)	0.4 (0.2–1.1)	0.5 (0.2–1.0)	0.5 (0.1–2.3)
High intensity (≤175 vs. >175 m)	0.8 (0.2–3.1)	0.9 (0.3–3.4)	2.9 (0.1–16.5)
Very-high intensity (≤9 vs. >9 m)	2.7 (1.2–6.5)†	0.7 (0.3–1.6)	0.6 (0.1–3.1)
Total high intensity (≤190 vs. >190 m)	0.5 (0.1–2.1)	1.8 (0.4–7.4)	0.7 (0.1–30.6)
Mild acceleration (≤186 vs. >186 m)	0.2 (0.1–0.4)‡	0.5 (0.2–1.1)	1.5 (0.3–8.6)
Moderate acceleration (≤217 vs. >217 m)	0.3 (0.1–0.6)‡	0.4 (0.2–0.9)†	1.4 (0.3–7.5)
Maximum acceleration (≤143 vs. >143 m)	0.4 (0.2–0.8)†	0.5 (0.2–0.9)†	1.8 (0.4–8.8)
Repeated high-intensity effort bouts (≤3 bouts vs. >3 bouts)	0.9 (0.4–2.0)	1.6 (0.8–3.3)	1.0 (0.2–4.4)

*All injuries were classified as a transient (no training missed), time loss (any injury resulting in missed training), or a missed match (any injury resulting in a subsequent missed match) injury.
†$p < 0.05$.
‡$p < 0.01$.

and R (version 2.12.1) (30) software were used to analyze the data. Based on a total of 101 injuries from 3,978 player-sessions (i.e., 34 players participating in 117 training sessions), the calculated statistical power to establish the relationship between running loads and soft-tissue injuries was ≥80% (5).

Results

The running loads performed during the preseason, early-competition, and late-competition phases of the season are shown in Table 1 and Figure 1. Total distances were higher in the preseason than in the early- and late-competition training phases.

The incidence of transient soft-tissue injuries was 37.4 (95% CI 26.7–51.0) per 1,000 hours. The incidence of injury resulting in time loss was approximately 3 times higher (42.1 [95% CI 30.7–56.3] per 1,000 hours) than that resulting in a missed match (13.1 [95% CI 7.2–22.0] per 1,000 hours). Wide running forwards had higher incidence rates for no time loss injuries (81.2 [95% CI 50.2–124.0] per 1,000 hours) than the other positional groups (Table 2). However, injuries resulting in time loss (71.8 [95% CI 38.2–122.8] per 1,000 hours) and missed matches (33.1 [95% CI 12.2–72.2] per 1,000 hours) were higher in the outside backs than in the other positional groups.

The distance covered in mild, moderate and maximum accelerations, and at moderate intensity movement velocities were found to be significant risk factors for no time loss injuries. Similar factors (distances covered in mild, moderate and maximum accelerations, and low-intensity movement velocities) were also found to predict the incidence rates for time loss injuries. Because of the small number of cases, no factors were found to be significantly related with missed match injuries (Table 3).

When adjusting other factors, the frailty model showed that the risk of no time loss injury was 2.7 (95% CI 1.2–6.5) times higher when very high-intensity running exceeded 9 m per session, compared with ≤9 m per session (Table 4). The distances covered in mild, moderate, and maximum accelerations were found to be significantly related with no time loss injuries; the higher the acceleration, the lower the risk of no time loss injuries (0.2 [95% CI 0.1–0.4] for mild acceleration; 0.3 [95% CI 0.1–0.6] for moderate acceleration; 0.4 [95% CI 0.2–0.8] for maximum acceleration). Very low- and low-intensity movement velocities and moderate and maximum accelerations were found to be significantly related to the risk of time loss injuries. A 60% lower risk of time loss injury was observed (relative risk 0.4, 95% CI 0.2–0.9) when very low-intensity running exceeded 542 m per session, compared with ≤542 m per session and when the distance covered in moderate acceleration activity was >217 m per session, compared with ≤217 m per session. The relative risk of injury was lower (relative risk 0.5, 95% CI 0.2–0.9) when the distance covered in low-intensity running was >2,342 m per session and maximum acceleration distance was >143 m per session.

Discussion

This study is the first to investigate the relationship between running loads and lower body soft-tissue injury risk in elite team sport athletes. This study also adds to the training-injury

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literature by using a novel emerging technology (i.e., GPS and associated microtechnology) commonly used to monitor training loads in the elite team sport environment. The results of this study demonstrate that greater amounts of very high–velocity running (i.e., sprinting) are associated with an increased relative risk of lower body soft-tissue injury. In addition, the relative risk of sustaining a soft-tissue injury was significantly lower in players who covered greater distances at very low, low, and moderate intensities. From an injury prevention perspective, these findings provide empirical support for restricting the amount of sprinting performed in preparation for elite team sport competition.

The incidence and relative risk of soft-tissue injury was lower in players who covered greater distances at very low (i.e., 0–1 $m \cdot s^{-1}$), low (i.e., 1–3 $m \cdot s^{-1}$), and moderate (i.e., 3–5 $m \cdot s^{-1}$) intensities. These findings are in direct contrast to our hypothesis that greater running volumes would be associated with a higher incidence of injury. Previous studies of military personnel have demonstrated that higher running volumes were associated with higher injury rates (29). A limitation of that study was that total weekly volumes were estimated and were not partitioned into the amount of running performed at low and high intensities. With advances in player tracking technology, we were able to measure total distances, and distances covered at low, moderate, and high velocities, maximal acceleration efforts, and RHIE (i.e., sprinting and tackling) bouts. Given the importance of tackling, collisions, and repeated efforts to physical performance in rugby league (22), and the likelihood that these highly intense activities could contribute to injury risk, it was thought imperative to quantify these activities relative to soft-tissue injuries. Although the average total distances performed in this study would not be considered excessive and are likely much lower than those performed by other team sport athletes where a greater emphasis is on running as a conditioning modality (e.g., Australian football), the present findings demonstrate that the total distance covered and distances covered at low and moderate speeds offer minimal soft-tissue injury risk, with distances covered at lower intensities actually providing a protective effect against soft-tissue injury.

Greater than 9 m of very high–intensity running (i.e., high-velocity sprinting) per session was associated with a 2.7 times greater relative risk of injury than low amounts of high-speed running. These findings highlight that the volume of high-speed running contributes significantly to injury risk in elite team sport athletes. Although 9 m of very high–velocity running per session is negligible, it should be noted that the majority of sprint efforts performed in team sports are short duration, maximal acceleration efforts that do not achieve maximal velocities (31). Moreover, higher volumes of mild, moderate, and maximum acceleration efforts were associated with a reduced relative risk of soft-tissue injury. Although these findings provide empirical support for limiting the amount of high-velocity sprinting performed in training sessions, a fine balance exists between restricting training loads for injury prevention purposes and increasing training loads to physically prepare players for the most demanding periods of competition. Indeed, the finding that relative training intensity (i.e., meters per minute) was not associated with soft-tissue injury risk should encourage coaches to maintain intensity within the training environment.

It should be noted that although the overall incidence of soft-tissue training injuries resulting in a missed match was high (13.1 per 1,000 training hours), no running variables were significantly associated with missed match injury risk. Furthermore, none of the running variables increased the relative risk of time loss injury, with low- and very-low velocity running, and distances covered in mild, moderate, and maximum accelerations offering a protective effect against time lost through soft-tissue injury. Although various running variables were associated with transient injury risk, these findings indicate that the running loads described in this study had minimal influence over the incidence or relative risk of severe (i.e., time loss or missed match) injuries.

Although the incidence of training injuries in this study (13.1 per 1,000 training hours) was lower than that previously reported for match injuries (60.3 per 1,000 playing hours) (23), injury rates were of sufficient concern to warrant an understanding of training demands and the relative risk of injury with different running loads. Although wide running forwards had the greatest incidence of transient injuries, soft-tissue injuries resulting in lost training time and missed matches were greatest in the outside backs positional group. Interestingly, the outside backs positional group have also been reported to perform more high-speed running, achieve higher absolute and relative velocities, and be involved in a greater number of maximal acceleration efforts during competition than any of the other rugby league positional groups (18).

In conclusion, this study investigated the relative risk of low- and high-intensity running loads on lower body soft-tissue injury in elite team sport athletes. The results of this study demonstrate that greater amounts of very high–velocity running (i.e., sprinting) are associated with an increased relative risk of lower body soft-tissue injury. From an injury prevention perspective, these findings provide empirical support for restricting the amount of sprinting performed in preparation for elite team sport competition.

PRACTICAL APPLICATIONS

The results of this study have several practical implications for the strength and conditioning coach. Although it has been suggested that high running volumes increase the risk of soft-tissue injury, evidence supporting the link between running loads and soft-tissue injury is far from substantive. Greater distances covered in very low, low, and moderate speed running were associated with a lower risk of soft-tissue injury, whereas greater amounts of very high–velocity running (i.e., sprinting) were associated with an increased risk of soft-tissue

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injury. Restricting the amount of sprinting performed in preparation for elite team sport competition may reduce the risk of soft-tissue injury; however, coaches should also consider the consequences of reducing training loads on the development of physical qualities and playing performance.

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Perspective

Covid-19 and the Need for Health Care Reform

Jaime S. King, J.D., Ph.D.

The Covid-19 pandemic has brought into sharp focus the need for health care reforms that promote universal access to affordable care. Although all aspects of U.S. health care will face incredible challenges in the coming months, the patchwork way we govern and pay for health care is unraveling in this time of crisis, leaving millions of people vulnerable and requiring swift, coordinated political action to ensure access to affordable care.

About half of Americans receive health coverage through their employer, and with record numbers filing for unemployment insurance, millions find themselves without health insurance in the midst of the largest pandemic in a century. Even those who maintain insurance coverage may find care unaffordable.

Before the pandemic, research showed that more than half of Americans with employer-sponsored health insurance had delayed or postponed recommended treatment for themselves or a family member in the previous year because of cost.[1] The loss of jobs, income, and health insurance associated with the pandemic will greatly exacerbate existing health care cost challenges for all Americans. For instance, in a recent poll, 68% of adults said the out-of-pocket costs they might have to pay would be very or somewhat important to their decision to seek care if they had symptoms of Covid-19.[2] Failure to receive testing and treatment because of cost harms everyone by prolonging the pandemic, increasing its morbidity and mortality, and exacerbating its economic impact.

To address myriad issues raised by Covid-19, Congress has passed two significant pieces of legislation, with more likely to come. The Families First Coronavirus Response Act (FFCRA) requires all private insurers, Medicare, Medicare Advantage, and Medicaid to cover Covid-19 testing and eliminate all cost sharing (copayments, deductibles, and coinsurance payments) associated with testing services during the public health emergency. It also appropriated $1 billion for the Public Health and Social Services Emergency Fund to cover testing for uninsured individuals under state Medicaid plans. Although the FFCRA assists with testing costs, patients remain vulnerable to cost-sharing expenses associated with treatment (such as hospitalization) until they reach their yearly out-of-pocket maximum, which can exceed $8,000 for an individual and $16,000 for a family.

The Coronavirus Aid, Relief, and Economic Security (CARES) Act, a $2.2 trillion pandemic-relief bill, requires all private plans to cover Covid-19 testing and future

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vaccines, but it stops short of eliminating cost sharing for Covid-19 treatment. Nonetheless, many private insurers, including Humana, Cigna, UnitedHealth Group, and Blue Cross Blue Shield, have agreed to waive cost-sharing payments for plan members treated for Covid-19. The CARES Act appropriated $100 billion for hospitals and health care providers, which Health and Human Services Secretary Alex Azar later conditioned on providers' agreement not to bill insured patients more than their in-network cost-sharing amounts and not to bill uninsured patients at all for Covid-19 treatment. The federal government will reimburse providers at Medicare rates for treating uninsured patients. The CARES Act also provided substantial tax credits, emergency grants, and loans to help businesses keep employees on the payroll or on furlough through June 2020, while extending and increasing unemployment benefits for those who lost their jobs.

Though these laws provide critical assistance, additional policies are needed to ensure that Americans can continue to access affordable care as the crisis continues. First, I believe policymakers should freeze people's insurance status as of April 1, 2020, to keep as many people as possible in their existing plans and with their current providers. People who had employer-sponsored insurance or an Affordable Care Act (ACA) marketplace plan as of that date should be able to remain on that plan through the end of the public health emergency, even if they lose their jobs or cannot pay their premiums. As an initial step in this direction, several states have instituted grace periods on insurance-premium payments for all policies.[3] For example, the Ohio Department of Insurance ordered all insurers to offer employers a 60-day grace period for premium payments, enabling them to retain employees and their health benefits for an extended period.[4] Premium payments could be paused, subsidized, or paid directly by federal disaster-relief funds.

Second, policymakers should secure coverage for people who have already lost their jobs by expanding access to ACA marketplace plans and Medicaid. Eleven states and the District of Columbia have opened new open enrollment periods for their state ACA marketplaces to encourage enrollment.[3] Despite President Donald Trump's announcement that he would not open enrollment in the 38 states with ACA plans hosted on the federal marketplace, people who have lost their jobs within the past 60 days or who expect to lose their job in the next 60 days can apply to enroll in an ACA marketplace plan during a special enrollment period (just as one can after a life event such as marriage or the birth of a child).

In response to the pandemic, nearly all states have received Section 1135 Medicaid waivers to meet the needs of their most vulnerable residents.[3] Many states sought such waivers to eliminate Covid-19–related cost sharing, facilitate provider and participant enrollment, and waive preauthorization requirements for Covid-19–related services during the declared public health emergency. In addition, many states (including Iowa, which already applied for and received a Medicaid waiver to be allowed to maintain its enrollment) will pause disenrollment to receive a higher federal matching rate established by the FFCRA. Finally, no state is currently enforcing work requirements for maintaining Medicaid eligibility.

Given the size and scope of the pandemic, state or federal government officials could also implement something similar to the Disaster Relief Medicaid program (DRM), a temporary public health insurance program created in New York after the 9/11 terrorist attacks.[5] The DRM allowed nearly 350,000 New Yorkers to quickly and easily obtain access to Medicaid benefits by raising eligibility thresholds, excluding asset tests, and using short-form applications. The program provided New Yorkers with 4 months of emergency Medicaid coverage during the most critical time of the crisis, and then helped them transition to other coverage. A similar emergency program could raise eligibility thresholds beyond Medicaid expansion levels and increase federal matching funds to help cover people who lost their jobs or remain uninsured during the pandemic.

Third, state and federal officials should continue addressing out-of-pocket expenses, such as cost sharing and surprise medical billing. Lawmakers can follow Massachusetts, New Mexico, and Washington, D.C., by eliminating cost sharing for Covid-19–related treatment. Hospital and provider reimbursement shortages can be covered by CARES Act appropriations.

Covid-19 also creates unique affordability challenges related to surprise medical billing, which can occur when a patient receives treatment from an out-of-network physician at an in-network facility. Staffing shortages and triage protocols make it more likely that patients will be sent to out-of-network facilities or be seen

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by out-of-network providers when they cannot check providers' network status. Furthermore, provider shortages may require providers to fill in care gaps for many conditions, not just Covid-19, expanding the potential for out-of-network care and surprise bills during this time. Though more than half the states offer some surprise-billing protections, policymakers should eliminate bills from out-of-network providers that exceed in-network cost-sharing limits for any medical treatment received during the public health emergency.

While states should continue leading the way on Covid-19 policies, comprehensive protections demand federal intervention. The Employee Retirement Income Security Act of 1974 (ERISA) prohibits state laws governing health insurance from applying to self-insured employer plans, typically offered by large employers such as Apple, Intuit, and Microsoft. As a result, current state surprise-billing protections, cost-sharing prohibitions, and coverage mandates will not apply to nearly 60% of Americans with employer-sponsored health insurance (nearly 30% of the population). ERISA thus leaves millions of people unprotected by state health care reforms. Absent a federal response, states can avoid some ERISA entanglements by directly prohibiting providers from charging cost-sharing rates for Covid-19 treatment and from surprise billing, but historically this approach has been politically infeasible. Perhaps Covid-19 provides the necessary impetus for change.

Never before has the interdependence of all our health, finances, and social fabric been so starkly visible. Never before has the need for health care reforms that ensure universal access to affordable care for all Americans been more apparent. Our policies on health and health care, both during this pandemic and in the future, should reflect this reality, and we should not let the lessons of this crisis pass us by.

Disclosure forms provided by the author are available at NEJM.org.

From the University of California Hastings College of the Law, San Francisco.

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