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## 8 **Effects of physical efforts on injury in elite soccer**

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24  
25 **Running head:** Physical performance and soccer injury

## 1 **Abstract**

2 In this study, the influence of physical efforts on occurrence of match injury in a  
3 professional soccer club was investigated. Computerised motion-analysis was used to  
4 measure the physical efforts of players during 10 injury situations. Total distance and  
5 those covered at different movement intensities were measured across the 5-minute  
6 period preceding injury. If the final run preceding injury involved a high-intensity  
7 action (HIA), the distance, duration and speed of the effort and the recovery time  
8 between this and the penultimate HIA were measured. To determine the influence of  
9 these physical efforts, the results were compared to a normative profile for players  
10 computed from data across 5 games for the same variables; habitual distances covered  
11 over a 5-minute period and characteristics of and recovery time between HIA.  
12 Compared to the normative profile, no differences were reported in physical  
13 characteristics during the period leading up to injury or for HIA although the latter were  
14 substantially higher in intensity (duration and distance). A lower than normal recovery  
15 time between HIA prior to injury was observed ( $35.6 \pm 16.8$  s versus  $98.8 \pm 17.5$  s,  
16  $p=0.003$ ). Within the limitations of the small sample, these findings may aid in further  
17 understanding injury and physical performance in elite soccer.

18  
19

20

21 **Key terms:** injuries, motion analysis, football incident analysis, fatigue

## 1 **Introduction**

2 Soccer (Association Football) is a complex contact sport with high physical, technical,  
3 tactical, and physiological demands at the elite level [10], and the risk of injury is  
4 considerable [26]. In order to suggest preventive strategies specific to soccer, it is  
5 necessary to have detailed information on the injury mechanisms involved. Previously,  
6 analysis of soccer incidents that combines game-specific and medical information has  
7 been employed to describe how injuries and high-risk situations of injury occur in  
8 match-play [1,2,3,5,23]. Examination of the playing situation, athlete-opponent  
9 interaction, and refereeing has highlighted the importance of tackling duels and heading  
10 duels as high risk situations. In addition, a critical incident technique was designed to  
11 identify behaviour with potential injury risk [32]; the findings emphasised tackling,  
12 receiving a tackle and charging an opponent as the circumstances with the highest injury  
13 potential.

14 A precise description of the inciting event is a key component in understanding  
15 the causes of injuries in sport [7]. In soccer, there is a need to investigate the effects of  
16 the physical efforts of players on the occurrence of injury [9]. The physical demands of  
17 match-play can now be easily and accurately investigated via information collected  
18 using computerised motion-analyses of player movements. Yet, to date, the effects of  
19 movement intensity when injuries are incurred has received scant attention.  
20 Furthermore, in the studies that have touched on this area [1,2,3,5], movement  
21 intensities were recorded subjectively and no comprehensive data were provided on  
22 specific running characteristics such as starting, average or maximal running speed or  
23 on the length or duration of actions. Similarly, no study has examined the possible  
24 effects of physical efforts prior to the injury situation. Related research by Rahnama et  
25 al. [32] reported an increase in critical incidents and injury risk in the first 15 min and in

1 the last 15 min compared to other periods of the game. The presumption was that injury  
2 risk was associated to the periods in which exercise intensity was highest when players  
3 were fresh and lowest when players experience fatigue during the game, but there were  
4 no measurements of players' movements recorded. As players commonly experience  
5 transient fatigue in match-play notably after periods of intense exercise [8,28], motion  
6 analysis techniques could be used to determine whether greater than usual periods of  
7 intense exercise or inadequate recovery time between high-intensity efforts predispose a  
8 player to injury [9,10].

9 Therefore, the aim of this investigation in an elite soccer club was to examine  
10 the physical efforts of players in the period leading up to and for the final running action  
11 in occurrences of injury in professional match-play.

12

### 13 **Methods**

14 In the present study, injuries sustained during competitive matches (a total of 54  
15 League matches from mid-season 2007-08 to end of season 2008-09) in players  
16 belonging to a 1st Division French League Club had been prospectively diagnosed and  
17 documented by the team's physician in a sports injury database (TeamSanté, Enora  
18 Technologies, Paris, France). Player consent and local ethics committee approval were  
19 obtained.

20 The methodologies and definitions of injury used in the present study closely  
21 follow those recommended by International Soccer Injury Consensus Groups [16,22]. A  
22 total of 47 injuries forcing a layoff of over 48 hours not including the day of injury  
23 [24,29] were available for analysis. Information including the type, location and cause  
24 of injury and the match period during which each injury occurred (matches were  
25 divided into six 15-minute periods, i.e., 0-15min, 15-30mins and 30-45mins for each

1 respective half) was available. Also stored in the database was information on whether  
2 the player was forced to leave the field due to injury and the total number of days the  
3 player could not participate fully in training and competition. This latter number was  
4 used to calculate the severity of injury [16]. The severity of each injury was defined as  
5 slight, minor, moderate, or major depending on whether the player was absent from  
6 training or competition for two to three days, four to seven days, one to four weeks, or  
7 more than four weeks respectively [24,29]. Finally, descriptive information on the final  
8 action at the time the injury was sustained and whether contact had occurred between  
9 players was recorded.

10         The occurrence of injuries in soccer match-play cannot always be clearly  
11 identified on video recordings [27]. Often there is no stoppage in play and players do  
12 not go down on the pitch to receive treatment and are subsequently substituted at half-  
13 time or receive treatment after the match [1]. Therefore, only injuries that had forced the  
14 player to immediately leave and not return to the field of play were included for  
15 investigation. This process also helped avoid the inclusion of situations where players  
16 intentionally lay down either to rest, feign injury or delay playing time [17]. To reduce  
17 the effects of opposition behaviour, only injury incidents where no foul-play was  
18 observed (decision by referee to award a free-kick) were considered. These strict  
19 inclusion criteria limited the total number of injuries to 17 (36.2% of the total injury  
20 sample obtained over the two seasons).

21         After retrospective review of the medical records by the same club physician  
22 who had diagnosed the injuries, each injury incident was cross-referenced to determine  
23 whether the match had been recorded and analysed by the multiple-camera player  
24 tracking system (AMISCO Pro, Sport-Universal Process, Nice, France) used by the club  
25 to evaluate physical, technical and tactical performance in competition. A validation of

1 this system has demonstrated high-levels of validity, accuracy and reliability in  
2 measuring player movements in elite soccer play [41]. If information from the system  
3 was available, the physical performance data were then used to measure the efforts of  
4 players over 5-minutes leading up to and during the injury situation. To obtain the time  
5 of injury, the club physician and the injured player reviewed the digital video recording  
6 of the injury incident and the time corresponding to the incident was obtained from the  
7 digital time code. Altogether, data were available for a total of 10 of the injuries (21.3%  
8 of the total injury sample).

9 To investigate the effects of physical performance prior to injury, the total  
10 distance and distance covered in four categories of movement intensity were measured  
11 over the 5-minute period preceding the time of injury: 0-11 km/h (walking, jogging or  
12 WJ); 11.1-14 km/h (low-intensity running or LI); 14.1-19 km/h (moderate-intensity  
13 running or MI); >19.1 km/h (high-intensity running or HI) [11]. To determine whether  
14 performance over this 5-minute period may have influenced injury, data across five  
15 completed matches were used in an attempt to establish a normative physical  
16 performance profile for each player [11,12]. For this profile, the total distance covered  
17 in each category of movement intensity was calculated for entire games. To calculate  
18 the distance covered over a 5-minute period, the total distance covered was divided by  
19 the match duration (in minutes) and then multiplied by 5. This figure was considered to  
20 be the player's habitual match-play activity level over a 5-minute period. The physical  
21 performance data used for the normative profile were based on information during the  
22 same season in which the injury occurred. The normative profile was subsequently  
23 compared to the physical efforts over the 5-minute period prior to injury.

24 The characteristics of the final running action in each injury situation were  
25 investigated. The starting and maximal running speed of actions and speed at time of

1 injury were documented as were the duration, distance covered and average speed of the  
2 movement.

3 It has been suggested that players may be more at risk of incurring injury during  
4 HI activities [9]. If the player reached a speed  $>19.1$  km/h for a minimum of 1 second  
5 duration at any time during the final running action, then the effort was considered to be  
6 a high-intensity run. Therefore, those injuries that had been identified as occurring  
7 during a HI exercise bout were investigated to determine whether the characteristics of  
8 these running actions differed from the player's habitual HI profile for this form of  
9 game activity. For this purpose, a normative profile was created for the speed, distance  
10 and duration of HI actions for five 90-minute games for each player and in which the  
11 player did not incur an injury. This result was compared to the same data obtained from  
12 each individual injury action.

13 Finally, to determine whether recovery time may have played a part in injury,  
14 the time between the penultimate HI effort and the HI action leading to injury was  
15 determined. Again, this result was compared to a normative profile for each player  
16 created from the calculation of the average recovery time between HI actions over five  
17 full games.

18 Statistical analyses of the dataset were performed using paired t-tests to test for  
19 differences in physical activity profiles prior to and during the injury situation and those  
20 obtained from the normative profiling of the same player's performances. The level of  
21 accepted statistical significance was set at  $p < 0.05$ . To control the Type-I error rate  
22 observed in multiple measures of physical performance in competitive soccer, a pseudo-  
23 Bonferroni's adjustment is used through dividing the alpha level by the number of  
24 categories in which objective measures of physical performance are classified  
25 [12,35,36]. In this case, the three normative profiles were utilised to compare

1 performance: physical efforts over a 5-minute period, characteristics of HI actions and  
2 recovery time between bouts of HI exercise. Thus, an operational alpha level of 0.017  
3 ( $p < 0.05/3$ ) was used. Effect sizes for these differences were also determined. Effect size  
4 values (using Hedge's adjustment for small sample sizes) of 0.2, 0.5 and above 0.8 were  
5 considered to represent small, intermediate and large differences, respectively (13).

6

## 7 **Results**

8 Information on the characteristics of injuries and the final running action in each injury  
9 situation is reported in Table 1.

10 Out of the 10 injuries, 60% were diagnosed as sprains while strains (20%),  
11 bruising (10%) and a combined fracture/dislocation (10%) were also recorded. Injuries  
12 to the ankle region were more common (50%) while the upper leg (30%) knee (20%)  
13 were also affected. Altogether, 80% of injuries were considered to be of moderate  
14 severity while the remaining part (20%) was classed as major injuries. Finally, only two  
15 injuries (20%) were sustained in the second half and a greater proportion of injuries  
16 (60%) involved physical contact between players.

17 The starting speed in all but one action was observed to be at low exercise  
18 intensity. Altogether, 8 out of 10 of the final running efforts before the injury was  
19 incurred involved a HI run ( $>19.1$  km/h) and the average speed of movement of these  
20 final actions was within the moderate-intensity range ( $\sim 17$  km/h). In a third of the  
21 movements (33.3%), the speed at the time the injury was sustained corresponded to  
22 moderate intensity.

23

24 Insert Table 1 about here.

25

1           The total distance and the distance covered at different intensities of movement  
2 in the 5-minutes prior to injury compared to the habitual physical performance profile of  
3 players are presented in Table 2. The lack of significant differences reported for any of  
4 these measures of physical performance were accompanied by insignificant to  
5 intermediate effect size differences. However, players covered around a third more  
6 distance (35%) at high running intensities before sustaining an injury compared to  
7 typical performance over a 5-minute period.

8           Also presented in Table 2 is information on the average speed, length, duration  
9 and recovery time of the eight HI actions that led to injury compared to the habitual  
10 characteristics of HI efforts in the same players. While no significant differences were  
11 obtained, results showed that these final HI actions leading to injury were almost double  
12 the length and duration of usual actions. These differences in action length and duration  
13 were accompanied by intermediate effect sizes ( $>0.5$ ). In contrast, the recovery time  
14 between the penultimate HI effort and the HI action leading to injury was shown to be  
15 significantly shorter compared to the habitual recovery time between HI bouts  
16 ( $p=0.003$ ). This difference was accompanied by a large effect size ( $>0.8$ ).

17

18 Insert Table 2 about here.

19

## 20 **Discussion**

21 The aim of this first study was to analyse the physical performance of elite soccer  
22 players in competition prior to and during actions leading to injury using motion  
23 analyses. Within the limitations of the small sample, the running actions in the injury  
24 cases indicated that at the time of injury, players were generally moving at moderate  
25 speeds after having started their final run at low speeds before attaining high intensities

1 and then reducing speed. Analysis of the characteristics of high-intensity bouts in the  
2 injury situation showed that these actions were greater in both distance and duration,  
3 albeit non-significantly, compared to the player's usual efforts. While the players'  
4 overall efforts in the 5-minute period leading up to injury did not seem to play a direct  
5 part in the injury, a significantly lower than normal recovery time between high-  
6 intensity actions prior to sustaining injury was observed.

7         A large proportion of injuries sustained in professional soccer players are  
8 sustained during running actions [24] but little is known about the characteristics of  
9 these movements. In the present study, analysis of the running actions in the match  
10 injury situation showed these involved relatively high movement speeds (~17 km/h).  
11 Review of the injury situations showed that games skills, physical contact and injury  
12 avoidance behaviours were also superimposed on the locomotor activities leading to  
13 injury. The majority of the final running actions initially involved an acceleration phase  
14 from low to high running intensities, attaining speeds of over 23 km/h (for example to  
15 create space or close a player down), before the player decelerated to moderate speeds  
16 (generally when attempting to gain possession) at which the injury occurred. These  
17 acceleration and deceleration characteristics of running actions are highly common to  
18 the game of soccer. In the latter, impairments in the eccentric muscle contractions  
19 involved in such phases may be linked to an increased risk of joint and muscle injury  
20 [21]. Indeed, a recent review on soccer performance has identified a need for specific  
21 deceleration exercises in strength and conditioning training sessions [9] which could  
22 have some relevance for preventing some of the injuries identified in this and other  
23 reports [24,29,40] on soccer match-play.

24         In elite soccer match-play, high-intensity actions are rarely more than 20 metres  
25 in length and greater than 4 seconds in duration [14,18]. The present results from the

1 normative analysis of player performance confirm this trend. While no significant  
2 differences were reported in distance or duration for the high-intensity run that led to  
3 injury, values for these measures were almost twice that of the normative profile. This  
4 finding suggests that players may be more at risk of injury when subjected to high-  
5 intensity bouts of exercise that are greater than usual in intensity. This observation  
6 could have important implications for the design of high-intensity running regimens.  
7 However, in the majority of the high-intensity actions that led to injury, players were in  
8 situations where they were challenging for possession. Further work combining injury  
9 and physical performance data is needed to examine whether the risk of injury is greater  
10 in situations where the player is tackling or being tackled which simply happen to be  
11 accompanied by high-intensity activities.

12         The physical efforts in the five minutes prior to the injury situation did not seem  
13 to play a role in causing injury. While players covered a slightly higher overall distance  
14 (+4%) than they would during a typical five-minute period of play, this result was not  
15 significant implying that fatigue was not a contributing factor to injury. However, the  
16 players had covered 35% more distance at high-intensities than usual before sustaining  
17 injury. Previous research in soccer match-play has shown that sprint performance is  
18 significantly reduced after the most intense periods of exercise indicating that players  
19 experience temporary fatigue [9,28,30]. The present players may have been  
20 experiencing some degree of fatigue due to their increased efforts notably at high-  
21 intensities thereby affecting their capacity to perform maximally during the injury  
22 action.

23         These findings are supported by a significantly shorter than usual recovery time  
24 (~36 seconds versus ~99 seconds in typical performance) observed between the  
25 penultimate high-intensity action and the one that led to injury. During multiple sprint

1 work, fatigue is manifested as a progressive decline in functional performance, the  
2 magnitude of which is largely determined by the duration of the intervening recovery  
3 periods [18]. Therefore, at the time of injury, the present players may have experienced  
4 transient fatigue due to incomplete recovery between high-intensity bouts increasing  
5 their susceptibility to injury. This reduction could have affected functional performance  
6 in areas such as proprioceptive ability [37], dynamic joint stability [25], force  
7 production [4], neuromuscular responses [19] or running mechanics [38]. However,  
8 caution is required when interpreting these results as to the validity of the method  
9 employed for determining a normative profile for each player over a 5-minute period.  
10 The work-rate pattern in soccer is random, can vary greatly across match periods and  
11 between games and depends on many factors such as scoreline or opposition standard.  
12 Nevertheless, researchers should be encouraged on the basis of the present study design  
13 and results to explore other means for creating a normative profile for work rate over  
14 pre-defined match periods.

15         These results may have important implications for the design of conditioning  
16 regimes to improve player fitness in an attempt to reduce the risk of injury. For  
17 example, high-intensity fitness training in soccer traditionally aims to improve the  
18 player's ability to recover quickly following successive bouts of high-intensity  
19 anaerobic efforts. This effect is achieved through an increased aerobic response,  
20 improved lactate removal, and enhanced phosphocreatine regeneration [18]. Specific  
21 high-intensity training regimens are traditionally based on work-rest ratios involving the  
22 repetition of runs over a set distance and with fixed recovery times [15]. However, the  
23 intensity of actions and recovery periods can alternate at any time according to the  
24 demands of the match which was the case during the injury incidents reported in this  
25 study. Therefore, to optimise player fitness and reduce the chance of injury,

1 practitioners could consider constructing high-intensity training programmes on the  
2 repetition of runs that vary in both intensity (duration, distance) and in recovery time.

3         These preliminary findings may also be pertinent for constructing exercise  
4 protocols to simulate the exercise intensities experienced during match-play to  
5 investigate the effects of fatigue on injury risk in muscle and joints. Previous  
6 experiments have successfully used soccer-specific exercise within the laboratory  
7 setting [20,21,31,33,34,39] to monitor changes in performance. However, these  
8 protocols tend to measure fatigue after fixed durations (e.g., start, middle and end of  
9 exercise) and use a 90-minute exercise period divided into 15-minute normative activity  
10 profiles that are identical in terms of intensity. These exercise protocols therefore do not  
11 represent the random nature of activity in soccer and on the basis of the present  
12 findings, we suggest that future research using such protocols should also investigate  
13 impairments in performance after periods of higher than average exercise intensity.

14         A major limitation of this study was the small number of injury cases examined.  
15 In studies of risk factors for sports injuries, a minimum of 20-50 injury cases is  
16 recommended [6]. It is inevitable though through comparisons with the low sample  
17 sizes obtained in other studies [2,4], that identifying large numbers of real time-loss  
18 injuries on video during elite soccer competition is difficult. This limitation of the low  
19 sample size is partly countered by the strict injury inclusion criteria combined with the  
20 simultaneous access to medical information from team medical staff resulting in a less  
21 biased description of how soccer injuries occur [3]. A further limitation was the cohort  
22 included players from only one soccer club (as detailed medical information on  
23 opposition injuries and physical performance was not available) and the patterns  
24 observed may only be a reflection of this particular team. Furthermore, the proportion of  
25 injury types (for example, 60% of injuries were sprains) investigated may not fully

1 represent the patterns of injury habitually reported in elite soccer match-play [24,40].  
2 Investigations involving a substantially larger sample of clubs and injury cases are  
3 therefore warranted. However, obtaining confidential information and in sufficient  
4 quantities on both physical performance and player injury during match-play from elite  
5 clubs is difficult. Similarly, no single research approach to identifying the reasons for  
6 injury is adequate in terms of completeness of information provided and it is necessary  
7 to combine a number of different approaches to describe the mechanisms fully [27]. For  
8 example, the impact of extrinsic factors such as the playing situation, game context and  
9 opponent behaviour could have affected the present findings. Nevertheless, important  
10 practical insights can be gained from studying the events preceding injury and this first  
11 investigation is a first step in identifying and understanding the relationship between  
12 physical performance and injury in elite soccer competition. It is hoped that similar  
13 research on injury data will be done in other professional clubs and associations to build  
14 upon the present findings by exploring some of the gaps and questions identified in this  
15 report.

16

## 17 **Conclusions**

18 The physical demands of contemporary professional soccer match-play are high and  
19 players are subjected to fatigue and risk of injury. The present study is the first to have  
20 shown that information on physical performance obtained from motion analyses of  
21 match-play may be valuable in increasing knowledge about the events involved in the  
22 occurrence of injury. These preliminary findings suggest that when there is inadequate  
23 time for recovery between high-intensity exercise bouts and the distance and duration of  
24 these actions are substantially higher than usual, players may be at increased risk of  
25 sustaining injury. Also, analysis of injuries showed that running actions involved both

1 an acceleration phase to achieve high speeds as well as a deceleration phase during  
2 which injuries were sustained. Whilst further research is evidently necessary, the  
3 findings from this and future studies may eventually be employed in injury prevention  
4 strategies by informing the prescription of specific fitness training protocols.

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1 **42 Table 1** Descriptive characteristics of injuries and movement data for the final running action leading to the injury.  
 2 **43**

Position	Type	Injury		Layoff time		Speed (km/h)			Duration (s)	Length (m)	In ball Possession	Contact	Qualitative description of game incident
		Location	Time in match	Start	At injury	Maximal	Average						
Defender	Sprain	Ankle	73rd minute	>1 month	0.6	8,0	12.1	9,0	1.6	4,0	No	No	Run then jump to head ball and injured when taking off
Defender	Sprain	Ankle	36th minute	1-4 weeks	12.7	17.5	19.2	18,0	2,0	10,0	No	Yes	Run to intercept ball and injured during challenge for possession
Defender	Sprain	Knee	7th minute	1-4 weeks	8,0	16.4	23.7	18.6	8.8	45.5	No	No	Run to close down opposition player followed by turn and injured during ensuing run
Defender	Sprain	Knee	85th minute	1-4 weeks	5.3	11.7	21.2	18,0	2,0	10,0	No	Yes	Run to intercept ball and injured during landing after challenge for possession
Defender	Sprain	Ankle	7th minute	1-4 weeks	10.9	11,0	11.3	11,0	2.5	11,0	No	Yes	Run to cover space and injured while challenging for possession
Defender	Strain	Groin	32nd minute	1-4 weeks	1.8	16.9	30,0	20.9	11.4	66.4	No	No	Run to meet pass and injured when controlling ball
Centre-forward	Fracture/dislocation	Ankle/Lower leg	25th minute	>1 month	5,0	12.8	22,0	16.1	5.6	25.1	No	Yes	Run to close down opposition player followed by turn and injured during ensuing tackle
Centre-forward	Bruising/Hematoma	Thigh	24th minute	1-4 weeks	5.4	9.4	26.6	21.2	11,0	64.7	No	Yes	Run to meet pass and injured during challenge for possession
Centre-forward	Sprain	Ankle	16th minute	1-4 weeks	9.2	19.3	30.2	16.9	5.1	24,0	No	Yes	Run into space and injured during challenge for possession
Centre-forward	Strain	Hamstring	23rd minute	1-4 weeks	2.9	18.7	22.4	16.2	6.5	29.2	Yes	No	Run into space to collect possession and injured when passing
Mean ± SD					6.2±4.0	14.2±4.2	23.0±6.5	16.6±3.8	5.7±3.7	29.0±22.7			

3 44  
 4 45  
 5 46Mean ± SD  
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1 47

2 **Table 2** Comparison between the players' normative physical performance profile over a typical 5-minute game period and the 5-minute period  
 3 leading up to the injury; and comparison between the normative physical performance profile for a typical high-intensity action and the high-  
 4 intensity action during which injury occurred.

5 48

	Normative	Injury Action	Mean difference	Effect Size
Distance covered in 5-min period leading to injury (m)				
Total	569.2 ± 28.2	594.5 ± 88.3	25.3 ± 84.8	0.36
High-intensity	44.2 ± 11.2	67.0 ± 57.3	22.8 ± 61.9	0.53
Moderate-intensity	82.0 ± 14.0	84.8 ± 45.5	2.8 ± 47.3	0.06
Low-intensity	81.7 ± 15.2	87.1 ± 31.4	5.4 ± 30.6	0.19
Walking/jogging	361.4 ± 6.0	355.6 ± 59.9	-5.8 ± 59.9	0.08
Characteristics of final high-intensity runs leading to injury (n=8)				
Length (m)	15.7 ± 0.4	27.6 ± 18.7	10.9 ± 18.8	0.71
Duration (s)	2.5 ± 0.1	4.2 ± 2.7	1.7 ± 2.7	0.50
Speed (km/h)	22.2 ± 0.2	22.0 ± 1.7	-0.2 ± 1.8	0.00
Recovery time after previous high-intensity run (s)	98.8 ± 17.5*	35.6 ± 16.8	-63.2 ± 26.6	3.50

6 49

7 50\* Significantly greater recovery time (p=0.003)

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9 52 Mean ± SD

10 53