Bahr, R., Reeser, J. C. (2012). New guidelines are needed to manage heat stress in elite sports – The Fédération Internationale de Volleyball (FIVB) Heat Stress Monitoring Programme. *British Journal of Sports Medicine, 46*, 805-809.

New guidelines are needed to manage heat stress in elite sports – The Fédération Internationale de Volleyball (FIVB) Heat Stress Monitoring Program

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ABSTRACT
Background: There seems to be a discrepancy between the available heat stress guidelines and the actual risk of heatrelated illness among professional beach volleyball players competing under hot and humid conditions.

Objective: To monitor heat stress and record cases of heatrelated medical forfeits on the Swatch FIVB Beach Volleyball World Tour.

Methods: The FIVB Heat Stress Monitoring Protocol covered events on the FIVB Beach Volleyball World Tour and FIVB Beach Volleyball World Championships during the 2009, 2010 and 2011 seasons (51 events, most of these doublegender). The protocol consisted of (1) measuring the Wet Bulb Globe Temperature (WBGT) on centre court prior to the start of every match, and (2) recording any heatrelated medical forfeits during the tournament.

Results: Data were collected during 48 of 51 events. There were 9 events where the peak WBGT exceeded the US Navy Black flag conditions of >32.3 °C and an additional 2 events where the peak WBGT exceeded 31 °C, (meeting Red flag conditions.) In 2 events, the average WBGT equaled at least 31 °C. One case of a medical forfeit related to heat stress was recorded over the 3-year surveillance period: an athlete whose fluid balance was compromised from a 3-day bout of acute gastroenteritis.

Conclusion: The incidence of significant heat illness among athletes competing on the FIVB Beach Volleyball World Tour appears to be quite low, even though weather conditions frequently result in a WBGT index >32 °C. Currently available guidelines appear to be inadequate to fully assess the risk of heat stress and too conservative to inform safety decisions in professional beach volleyball.

INTRODUCTION
During a professional FIVB Beach Volleyball World Tour Grand Slam event in 2007, one team forfeited the final when a player could not continue competing due to the effects of heat stress. Although the athlete subsequently recovered fully, the outcome could have been much worse. There are numerous examples of athletes in other sports who have died from exertional heatrelated illness (particularly American football, perhaps due to the protective clothing/equipment worn).[1]

During this 2007 event, the maximum recorded air temperature was 34 °C and the maximum recorded wet bulb globe temperature (WBGT) was 32 °C. The WBGT is a composite value used to estimate the combined effect of temperature, humidity, wind speed (wind chill) and solar radiation on humans.[2] The WBGT is generally considered to be the best measure of heat stress. It is used by industry and the military to determine appropriate occupational exposure levels to temperature extremes. It is derived from a simple formula which incorporates the effects of wet bulb temperature (an indicator or humidity), black globe temperature (a measure of solar radiation) and normal air temperature. Instruments that measure WBGT also factor in any evaporative wind cooling effect.

Several systems utilizing the WBGT have been developed in order to estimate the risk of developing heat illness under varying environmental conditions. Historically, the National Athletic Trainer's Association,[2] the American College of Sports Medicine (ACSM) [3] and the United States Navy[4, 5] have adopted the "warning flag" concept to indicate the level of risk from exposure to high heat and humidity. In their original iterations, it was clear that the US Naval system (also employed by the United States Marine Corps) was less conservative than the ACSM system. The reasoning was evident: the ACSM guideline was prepared to describe the potential risks to a broad range of athletic participants who may be in various states of conditioning and acclimatization, while the Navy was understandably more confident in its ability to control key risk factors for heat stress, most notably acclimatization and the general fitness level of its soldiers. In 2007, however, the ACSM revised its position stand3 and warning system to account for the physiological differences and relative risk reduction that accrue through acclimatization and fitness, as well as through intermittent activity (as opposed continuous activity, which carries higher risk). The revised ACSM guideline states that uncompensable heat stress exists for all types of activity for all athletes when the WBGT reading exceeds 32.3 °C. This is equivalent to the US Navy black flag condition, considered to be the upper limit for physical activity in hot and humid conditions.

In response to the heat stress related forfeit alluded to earlier, the FIVB Medical Commission sought to better understand the magnitude of the risk for heat illness on the FIVB Beach Volleyball World Tour by undertaking a retrospective analysis of the maximum temperature and associated humidity conditions that occurred during each of the 72 Swatch FIVB World Tour events contested between 20042007. The study analyzed historical weather data for each of the cities (or the general geographic region) that hosted a World Tour event during the interval in question. Based on this analysis, it became apparent that potentially dangerous weather conditions occurred during an alarmingly high number of tournaments over this 4year period. Based upon the calculated WBGT, roughly 13% of the World Tour events experienced a WBGT of at least 32 °C (i.e. essentially a US Navy "black flag" condition) at some point during the competition (Jonathan Reeser, unpublished data, September 2007).

An acknowledged limitation of our retrospective analysis was that it relied on weather data recorded from official meteorological recording sites (usually airports), and such data clearly do not necessarily reflect the actual courtside conditions to which the athletes were subject at the various venues. Another weakness was that no data were available on the incidence of heatrelated illness on tour during the same period, as there was no systematic surveillance mechanism in place at that time. However, anecdotal evidence provided by players, FIVB officials and FIVB Medical Commission members suggested that there had been only a very few cases of medical forfeits due to heat exhaustion on the World Tour during the 4year retrospective period. Furthermore, such historical recall identified no cases in which an athlete suffered serious or lingering health consequences due to heat illness, probably reflecting the fact that virtually all athletes on tour are well acclimatized to the heat, and that the players were experienced and well educated on safe hydration practices. In addition, beach volleyball (in contrast to marathon running, for example) is an intermittent activity with designed breaks during each game, allowing players to briefly rest and rehydrate, thereby reducing the risk of developing serious heat illness.

This preliminary investigation therefore revealed what seemed to be a discrepancy between the degree of risk implied by the available heat stress guidelines and the actual occurrence of heatrelated illness among the professional athletes competing on the beach volleyball World Tour. Consequently, in 2009 the FIVB decided to establish a surveillance program to prospectively monitor heat stress and record any cases of heatrelated medical forfeits on the Swatch FIVB Beach Volleyball World Tour.

METHODS

Implemented in 2009, the FIVB heat stress monitoring protocol has consisted of two elements: 1) recording WBGT measurements obtained on centre court of the competition venue prior to the start of all matches on that court, and 2) identification and recording of any heatrelated medical forfeits during the tournament. Data collection and reporting has been the responsibility of the FIVB Referee Delegate (Supervisor of Referees).

Exposures

The FIVB Beach Volleyball World Tour consists of a series of about 15 tournaments for each gender every year. Regular tournaments are formatted as a 32team doubleelimination bracket, resulting in a total of 62 matches played over 3 days for each gender. Grand Slam tournaments also include 32 teams per gender, but due to a different competition schedule, a total of 72 matches are played over 4 days. In addition, before the main draw of each tournament, a 2day qualification tournament is played in which 30 to 50 teams compete for eight spots in the main draw. Thus, a team might play up to seven matches to qualify and then between two and eight matches in the main tournament each week. The World Championships are contested in still another format, with a total of 48 teams qualified based on the world rankings. Beach volleyball matches consist of two games to 21 points, with a third “tie breaker” game to 15 points (if necessary). The average duration of a match is about 45 min, but matches may last up to 90 min. Approximately 1000 athletes have competed on the World Tour each season for which heat stress data are available.

WBGT measurements

WBGT measurements were taken in front of the scorer’s table on center court 5 min before the start of each match. If the scorer’s table was shaded, the measurement was made in a sunny area closer to the court or on the court. Measurements were taken on center court only; no data were recorded from the outside courts. Measurements were made by a reserve referee or the referee of the preceding match, using a commercially available heat stress meter (Model HT30, Extech Technology, USA). The device, which was positioned approximately
1.5 m above the sand, was used according to the manufacturer’s instructions. Specifically, the protective sliding cover was opened to allow air to flow through and the meter was set for outside mode, regardless if there was direct sun exposure or not. The alarm settings were functionally disabled by setting them to the maximum limit. The data collection procedures were reviewed during the referee's clinic before the start of each tournament.

The following data were recorded prior to each match on centre court:

- wet bulb globe temperature (WBGT, °C)
- air temperature (TA, °C)

- black globe temperature (TG, °C)
- relative humidity (RH, %)

Upon collection, data were recorded onto a Heat Stress Monitoring Form, then entered into an Excel file. Each day the referee delegate reviewed the data forms with the Excel file to ensure accuracy.

The daily mean temperature was computed and the average venue temperature was calculated as the average of the daily mean temperature. The peak temperature was the highest temperature recorded during the tournament. The average daily peak was calculated as the mean of the daily peak values recorded.

Recording of heatrelated medical forfeits
A medical forfeit is defined by the FIVB as the withdrawal of an athlete from competition for medical reasons. In such cases, the match referee is instructed to inquire if the withdrawal was prompted by symptoms of heat illness and/or dehydration. If so, the player is also asked if he/she had suffered from diarrhea or symptoms of gastroenteritis during any of the preceding five days. This information was noted on the score sheet and reported to the Referee Delegate, who was responsible for including it in the Excel file.

RESULTS
Of the 51 tournaments eligible for data collection, the Heat Stress Monitoring Protocol was followed and data were collected during all but three events (Mylowice, Poland in 2010, and Brasilia, Brazil and Prague, Czech Republic in 2011).

Figure 1 depicts the peak and average WBGT recorded during each of the 48 events. As shown, there were 9 events where the peak WBGT met the US Navy black flag condition of >32.3 °C and an additional 2 events where the peak WBGT exceeded 31 °C (US Navy red flag conditions). In 2 events, the average WBGT at least equaled 31 °C.

Detailed weather data for the 11 events for which peak WBGT exceeded 31 °C are shown in Table 1.

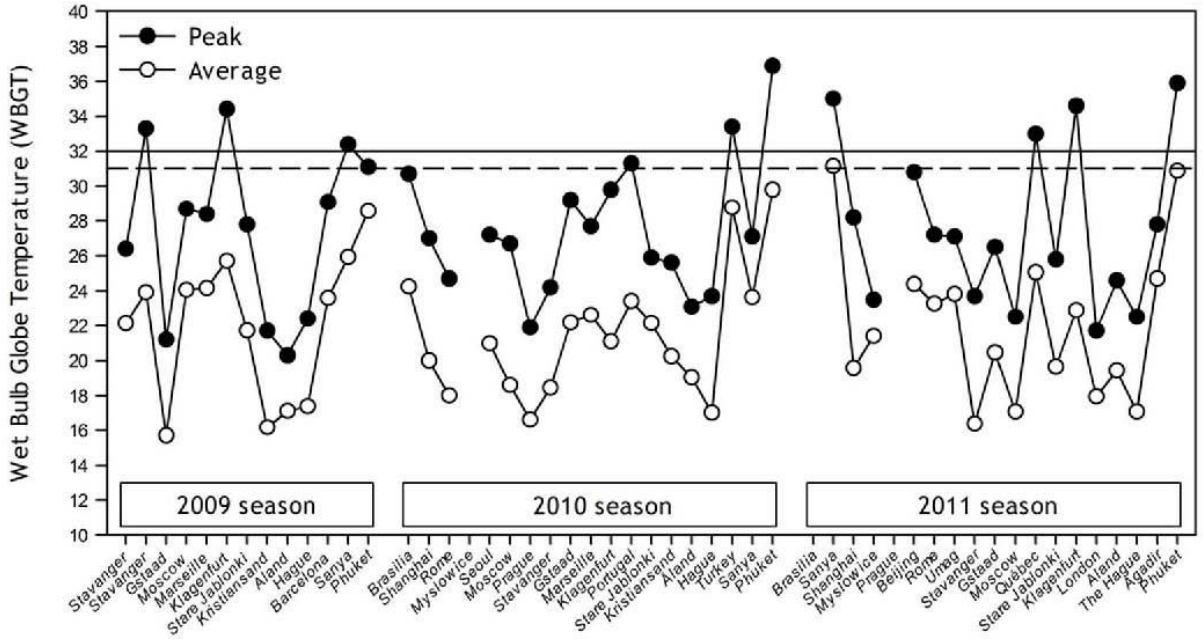

Figure 1. Peak (solid symbols) and average (open symbols) WBGT recorded during 48 of 51 FIVB beach volleyball events during the 20092011 seasons. The solid line represents US Navy black flag conditions of a WBGT >32.3, while the dashed line corresponds to red flag conditions. 100x54mm (300 x 300 DPI)

Table 1. Detailed results for the 11 tournaments where the peak WBGT exceeded 31°C. WBGT: Wet bulb globe temperature, TA: Air temperature, BG: Black globe temperature, RH: Relative humidity.

			Average				Peak				Average daily peak			
Dates	Country	Event	WBGT (°C)	TA (°C)	BG (°C)	RH (%)	WBGT (°C)	TA (°C)	BG (°C)	RH (%)	WBGT (°C)	TA (°C)	BG (°C)	RH (%)
2009														
July 1–4	Norway	Stavanger	23.9	28.2	38.9	38.3	33.3	33.2	54.3	53.1	28.2	31.0	49.2	50.2
July 27–August 2	Austria	Klagenfurt	25.7	31.6	42.9	37.4	34.4	44.8	67.3	72.8	30.3	38.8	57.5	62.1
October 26–November 1	China	Sanya	25.9	31.3	38.0	44.9	32.4	37.8	62.4	83.3	28.9	35.1	48.8	65.6
November 3–8	Thailand	Phuket	28.6	32.0	40.9	54.3	31.1	38.0	53.2	85.2	30.0	34.1	47.3	67.2
2010														
July 28–August 1	Portugal	Porto	23.4	25.9	38.1	51.3	31.3	33.5	54.8	73.5	26.3	29.1	47.2	65.6
September 15–19	Turkey	Alanya	28.8	33.5	41.3	50.1	33.4	42.1	54.6	65.6	31.5	38.3	46.8	59.8
November 2–7	Thailand	Phuket	29.8	32.3	38.3	60.3	36.9	40.1	49.9	87.0	32.5	34.5	43.0	72.1
2011														
April 26–May 1	China	Sanya	31.1	34.0	43.1	57.6	35.0	40.7	60.3	91.0	33.4	36.6	49.2	76.0
July 18–24	Canada	Québec	25.1	30.6	35.8	50.2	33.0	40.3	54.1	99.9	28.4	36.0	44.6	60.8
August 1–7	Austria	Klagenfurt	22.9	27.5	34.1	48.2	34.6	39.9	59.4	71.1	26.7	32.6	44.2	64.2
November 1–6	Thailand	Phuket	30.9	33.6	43.8	58.3	35.9	40.9	63.8	83.0	33.7	36.9	53.8	72.2

Only one case of a medical forfeiture related to heat stress was recorded during the three seasons for which the surveillance system data were recorded. This occurred in a male European athlete whose fluid balance was compromised from a 3day bout of acute gastroenteritis, and who was playing his 5th match over 3 days. In that event, which took place in China, the average air temperature was 31.3 °C, and the average and peak WBGT were 25.9 °C and 32.4 °C, respectively.

DISCUSSION

The main finding of this study is that beach volleyball appears to have a very low incidence of severe heat illness despite frequent exposure to conditions of high temperature and humidity. As such, the men and women competing on the FIVB Beach Volleyball World Tour would appear to have a low risk of developing exertional heat illness, despite playing in conditions that have been described as effectively intolerable. Taken together, the findings suggest that currently available guidelines may be of little help to fully inform decisions regarding when play should be suspended on the FIVB World Tour.

There are some limitations which need to be borne in mind when interpreting the results of the current study. First, the handheld WBGT devices used in the surveillance program are less sophisticated than the more advanced equipment used by meteorological services. Consequently, they are more prone to operator error (e.g. not opening the slide cover to allow airflow through the meter). Also, a large number of referees were involved in taking the measurements and recording the data, making it more likely that mistakes may have been made and unintentionally overlooked.

The proportion of tournaments with at least one black Flag condition (peak WBGT exceeding 32) during the 20092011 study period was 19%, which is slightly higher than the 13% of tournaments with such conditions retrospectively estimated for the 20042007 seasons. Although this difference may be explained by natural climate variation and/or changes in venue locations, it is also possible that the variation may be a result of the fact that the measurements were made on center court in 3,000to 5,000seat stadia. Conditions in such environments would be expected to be hotter than on nonenclosed courts, as the tribune can reduce the air flow. Regardless, it seems reasonable to conclude that the weather data recorded by the Heat Stress Monitoring Protocol are reasonable compared to the data derived from meteorological archives, and certainly should be more specific to the conditions experienced by the players within the venue compared to the historical data described.

The second limitation is our reliance on selfidentified heatrelated medical forfeits as the main outcome measure. This means, of course, that any athlete suffering from mild dehydration or other symptoms of mild heat illness may not have been identified. These “minor cases” of heat illness would simply not have been recorded (even if the athlete’s performance level was affected), unless the player chose to withdraw from competition. We decided to use this protocol for the following reasons: 1) We wanted to capture incidents with a significant impact on the athlete’s health and we reasoned that by recording forfeits that we would identify only those cases of serious heat illness; 2) as these are extremely motivated professional athletes, the selection of forfeits would minimize “false positive”

instances (i.e. there would be no benefit to faking a medical forfeit); 3) the FIVB World Tour referees represent a highly trained group of dedicated individuals who are closely supervised by the FIVB Referee Delegates, and are trained to follow all manner of procedures to the letter. We therefore believed that we could rely on them to obey the Heat Stress Monitoring Protocol and collect the data reliably. An alternative would have been to have the tournament medical team monitor cases. However, when the study began, the medical services at each event were managed locally, and we did not trust our ability to inform and train the local medical teams to record the data as reliably as the referees. Nevertheless, had there been severe cases of heat stress requiring medical intervention or hospitalization these would have become known to us through the various FIVB officials working on the tour.

A third limitation is that the number of exposures is limited, even after 3 years of data collection. Data was collected during 48 events, 11 of which experienced a peak WBGT of 31 °C or above. Considering that each event involves a minimum of 32 teams (64 players) and at least 62 matches for each gender, this means that we have collected representative data on close to 6000 matches, of which more than 1000 matches have been played under hot and humid conditions. We plan to continue data collection in order to obtain a broader sample.

Keeping these limitations in mind, our data suggest that professional beach volleyball is quite safe as it is being practiced on the FIVB Beach Volleyball World Tour. Despite conditions that would have merited a US Navy black flag in nearly one fifth of tournaments, and for which the heat stress is generally felt to be uncompensable, only one athlete withdrew from competition due to symptoms of heat illness. Athletic performance can be severely impaired in a hot environment,[6] and there is ample evidence to show that exercise in the heat poses a severe challenge to cardiovascular, thermoregulatory, metabolic, neural and cognitive function.[712] Still, our experience suggests that the magnitude of the deleterious effects of heat stress on performance differs in a sportspecific fashion, depending upon the unique activity patterns, duration and intensity of the sport.

There are several theories which can help explain why beach volleyball players are able to tolerate the extreme conditions regularly encountered on the World Tour. First, they are highly heatacclimated. Even players from the Northern hemisphere usually spend most of the winter months training in warm climates, e.g. Brazil. Second, they are experienced and very fit. It takes many years of training and competition at lower levels to qualify for the World Tour (the average age ranges in the late 20s, many players are in their 30s). Third, beach volleyball is an intermittent game. Matches consist of two rallyscoring sets to 21 points (win by 2), with a third set to 15 points played only if the first two sets are split. The average game lasts approximately 20 min and the average match lasts approximately 45 min, although contests in excess of 90 min have been documented. Rallies typically last an average of 8.1 s, and the mean time from the end of a rally to the whistle for next service is 17.1 s.[13] In other words, the work to rest ratio is about 1 to 2.1. In addition, there are side switches between every 7th point. In addition, teams have the opportunity to sit down and rehydrate during timeouts: there is one technical timeout about halfway through the game (after 21 rallies), and one timeout is allocated to each team per game to be used at their own discretion. If we assume that all available time outs are used per game, then in addition to side switches there are 3 breaks of approximately 1 min during which players can rest in

the shaded player's boxes and drink. This means that the heat stress during a professional beach volleyball competition is very different than that experienced during continuous, endurance sports, such as marathon running, or other team sports with few stoppages in play, such as football.

It is therefore not surprising that the results of the FIVB Heat Stress Surveillance System indicate that the available guidelines (US Navy, ACSM, others) are too conservative to guide decisions regarding whether or not it is safe to let a tournament continue in this setting. If a WBGT limit of >32.3 °C were strictly enforced, as many as 15% of the tournaments on the World Tour over the past three seasons would have been significantly delayed or cancelled altogether. Our data suggest that such precautions would be largely unwarranted.
Although outright cancellation of Tour events seems unwarranted, in fact preventive measures are recommended when conditions of heat and humidity become oppressive. During the three seasons in question, whenever the WBGT index was likely to exceed 31°C, the following preventive measures should be considered:

- Schedule matches in the morning and the evening to avoid the heat of the day;
- Permit side changes (with rest and water breaks) every 5 points (instead of every 7);
- Increase the time permissible between rallies;
- Provide each team with an extra timeout per set to use at their discretion.

These guidelines were outlined in the FIVB Beach Volleyball Handbook,[14] which serves as a detailed set of rules and regulations for organizers and officials. It merits noting that these preventive measures are to be employed at the discretion of the FIVB Technical Supervisor and Referee Delegate, and only once (out of 11 tournaments with a peak WBGT of 31 °C or greater) were these precautions implemented during the three seasons for which weather data was collected (the tournament in question experienced an average WBGT of 30.9 °C, and a peak WBGT of 35.9 °C).

CONCLUSION

The incidence of significant heat illness in professional beach volleyball on the World Tour is low, even though hot and humid conditions exceeding US Navy Black flag conditions (WBGT >32.3 °C) are encountered frequently. Currently available heat stress guidelines are too conservative to assess the sportspecific risk of heat illness, and thus to help inform reasonable safety decisions.

WHAT IS KNOWN ON THIS SUBJECT

- There are numerous examples of athletes in other sports (particularly American football) who have died from exertional heatrelated illness.

WHAT THIS STUDY ADDS

- The incidence of significant heat illness in professional beach volleyball on the World Tour is low, even though hot and humid conditions exceeding are encountered frequently.

- Currently available heat stress guidelines are inadequate to fully appreciate the sportspecific risk of heat illness, and thus to help inform reasonable safety decisions.

ACKNOWLEDGMENTS
We would like to thank our colleagues on the FIVB Medical Commission for their help in establishing the FIVB policies and procedures on heat stress management. A special thanks to Mr. Angelo Squeo, FIVB Beach Events Director, Mr. José Casanova, FIVB Beach Volleyball Referee Commissioner, FIVB Referee Supervisors and FIVB Referees for their continued support on the FIVB Heat Stress Management Program.

FUNDING
The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the SouthEastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS.

ETHICAL APPROVAL
This study has not been submitted for review by a medical research ethics committee.

CONTRIBUTORSHIP STATEMENT
RB and JR designed the FIVB Heat Stress Monitoring Program, RB monitored data collection and analyzed the weather data. RB and JR jointly interpreted the data and wrote the paper. RB is responsible for the overall content as guarantor.

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