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Fluid intake is a strong predictor of outdoor team sport pre-season training performance

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ABSTRACT

Our aim was to characterize fluid intake during outdoor team sport training and use generalized additive models to quantify interactions with the environment and performance. Fluid intake, body mass (BM) and internal/external training load data were recorded for male rugby union ($n = 19$) and soccer ($n = 19$) athletes before/after field training sessions throughout an 11-week preseason (357 observations). Running performance (GPS) and environmental conditions were recorded each session and generalized additive models were applied in the analysis of data. Mean body mass loss throughout all training sessions was −1.11 ± 0.63 kg (~1.3%) compared with a mean fluid intake at each session of 958 ± 476 mL during the experimental period. For sessions >110 min, when fluid intake reached ~10–19 mL·kg^{-1} BM the total distance increased (7.47 to 8.06 km, 7.6%; $P = 0.049$). Fluid intake above ~10 mL·kg^{-1} BM was associated with a 4.1% increase in high-speed running distance ($P < 0.0001$). Most outdoor team sport athletes fail to match fluid loss during training, and fluid intake is a strong predictor of running performance. Improved hydration practices during training should be beneficial and we provide a practical ingestion range to promote improved exercise capacity in outdoor team sport training sessions.

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Hydration; fluid intake; sweat rate; team sport; training performance

Introduction

Fluid loss as a result of excessive sweat loss can limit performance and negatively impact perceptual responses to training (Casa, 2018; Cheuvront et al., 2005; Funnell et al., 2019). Team sports are typically characterized by high-intensity exercise interspersed with periods of low-intensity exercise or rest (Billaut et al., 2012) and the physiological demands during field-based training performance generate high sweat rates and fluid loss (Baker et al., 2016; Nuccio et al., 2017). Shirreffs and co-workers (Shirreffs et al., 2005) have previously reported that elite soccer athletes failed to ingest a sufficient volume of fluid to replace sweat loss during training sessions in high ambient temperature (T_a), with only ~45% of fluid and 23% of sweat sodium lost due to sweating replaced during the session. Similarly, it has also been suggested that athletes are unable to adequately match fluid intake to sweat loss during field training for rugby union (only 56% replaced) (Cosgrove et al., 2014). Of note, team sport athletes have unique physical attributes and sport-related requirements affecting fluid balance compared with endurance training counterparts. Moreover, sweat rates of team sport athletes have been shown to be markedly different than endurance athletes (Godek, 2005). It is likely that larger body mass (BM), body surface area and specific clothing/equipment are contributing factors promoting increased sweat rates in team sport athletes (Godek, 2005).

The majority of previous studies determining fluid balance and sweat rate and effect on performance have focused on endurance athletes, and there is limited available information on the impact of fluid balance and sweat rate on outdoor team sport performance throughout pre-season preparation or competition (Nuccio et al., 2017). This is likely due to the complexity of quantifying performance in the outdoor team sport context, including skill execution, technique/technical demands and physical collisions. Consequently, previous studies have been limited to examining perceptual responses and performance outcomes from isolated physiological tests of team sport athletes (Ali & Williams, 2013). To better define the effects of fluid intake during outdoor team sport training it is reasonable to suggest that ecological validity should be a primary consideration but to achieve this, alternate methods are needed. In this regard, generalized additive models (GAMs) are a powerful technique for interrogating large, non-linear data sets obtained during routine training sessions to determine meaningful relationships among variables without interference or interruption of habitual coach and athlete practices (Woods et al., 2017).

Better understanding of the physiological and perceptual impact of fluid balance and sweat rate during pre-season training is essential to optimizing physical preparation for team sport athletes. Accordingly, the primary aim of this study was

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to determine the effects of fluid balance on field-based running performance for two different outdoor team sports, rugby union and soccer, during the pre-season preparatory phase. We first characterized the fluid intake and fluid loss during multiple training sessions in which global positioning system (GPS) data were recorded, and then applied GAMs to quantify the interactions among the environment, fluid intake and training performance. We hypothesized that during training inadequate fluid intake relative to sweat loss would decrease work completed and increase perceptual responses to exercise.

Methods

Participants

A total of 38 semi-professional male athletes from rugby union ($n = 19$, BM 99.5 ± 14.6 kg) and soccer ($n = 19$, BM 72.6 ± 5.7 kg) volunteered to participate in the study. Participants were preparing to compete in the Queensland State Premier Rugby or National Premier League Soccer Queensland competitions and were undertaking two extensive outdoor field training sessions and two high-intensity resistance training sessions each week, and simulation, trial or pre-season competition matches equivalent to fortnightly (rugby) or weekly (soccer) during the final 8 weeks of the 11-week experimental period.

Experimental procedures

Data including BM, fluid intake and internal/external training loads were captured at field training sessions throughout an 11-week pre-season preparation experimental period during January to April in Australia. Environmental conditions were recorded at each training session for inclusion in the subsequent data analysis. Training sessions commenced at 1800 h and 1830–1900 h in the evenings for rugby and soccer, respectively. Data were collected as part of the routine sport science program for each sport and did not interfere with pre-season training plans of staff and coaches to ensure that data collected were representative of the population and typical pre-season training regimen. There were 357 total observations included in the final analysis.

External training load

Each participant's external training load was quantified using GPS devices (PlayerTek; Catapult Sports, Melbourne, Australia). Participants were provided with the same GPS unit for each training session to minimize technical error and promote reliability (Scott et al., 2016). Participants were provided GPS units prior to training, with data recorded throughout the session. Total distance (m), distance per minute (m·min^{-1}), distance completed at various running velocities (high speed running [HSR] >18 km·h^{-1}, running 11–18 km·h^{-1}, jogging or walking <11 km·h^{-1}) (Dwyer & Gabbett, 2012; Gabbett & Ullah, 2012), and the maximum velocity (km·h^{-1}) were recorded. Maximum velocity recorded throughout the experimental period was 33.9 km·h^{-1} for rugby and 35.1 km·h^{-1} for soccer. The mean maximum velocity recorded for rugby and soccer within sessions were 26.5 km·h^{-1} and 28.2 km·h^{-1}, respectively. Once the session was complete, units were returned, and data were uploaded to the manufacturers' online platform and subsequently downloaded into a customized Microsoft Excel spreadsheet for analysis. Data were only included for analysis when participants completed the entire training session. Distance per minute data were collected for total training movement time excluding break/recovery time.

Internal training load

The rating of perceived exertion (RPE) for each session was obtained from the participants ~5 min after the completion of training. RPE was collected using the Borg CR-10 scale (Borg, 1982), with 0 representing no perceived exertion and 10 representing maximal perceived exertion from the session.

Body mass, fluid intake and sweat loss

Participants wore the same clothing (shirt or singlet and shorts) during each training session. Before and after each session, nude BM was recorded using standardized weighing scales (Personal Precision Scale UC-321, A&D, South Australia, Australia and Seca 803, Seca, Hamburg, Germany) measured to the nearest 10 g for calculation of BM pre- to post-session. No participants had need for urinary void during any training session for rugby or soccer. Participants were provided with towels by the researchers and instructed to dry their entire body prior to each measurement.

Participants were allocated their own individual drink bottle, which was weighed to the nearest 1 g pre- and post-training at every session (A&D HT-300, A&D, South Australia, Australia). Participants were instructed to maintain typical drinking behaviours (ad libitum) throughout the training session. If the bottle was near empty at any stage, it was weighed to determine the amount consumed and re-filled, re-weighed and made available to the participant for the remainder of the session. The number and duration of drinking opportunities were compiled for each training session.

Fluid balance was calculated through differences in participant BM before and after training and adjusting for fluid ingested during the training sessions. Whole-body sweat loss (WBSL) and rate (WBSR; L·h^{-1}) were calculated using the following formulas:

WBSL (L)

(Pre BM (kg) − (Post BM (kg) + Total fluid intake (L) - Urine loss (L))

WBSR (L·h^{-1})

WBSL/Duration in hours

Percentage (%) BM loss was calculated using the following formula:

(Pre session BM − Post session BM)/Pre session BM

Fluid intake (mL·kg·min^{-1}) was calculated by dividing total session fluid intake by BM, which was subsequently divided by duration (min) for each session.

Table 1. Environmental conditions during training sessions for rugby union ($n = 15$) and soccer ($n = 14$) throughout an 11 week pre-season preparation experimental period.

	Rugby		Soccer		Combined
	Mean	Range	Mean	Range	Mean
Ambient temperature, °C	22.6 ± 2.39	17.6–26.1	23.9 ± 2.63	17.0–28.9	23.2 ± 2.59
Relative humidity, %	79.8 ± 8.71 *	65.1–96.7	72.6 ± 9.06	48.6–86.1	76.6 ± 9.57
Wind speed, km·h^{-1}	0.37 ± 0.29	0.00–1.08	0.54 ± 0.53	0.01–2.06	0.45 ± 0.42
WBGT, °C	20.9 ± 2.16	16.2–24.0	20.3 ± 2.39	14.6–24.0	20.6 ± 2.31

Note: Data are presented as mean ± SD and range, * Denotes significant difference between sports $P < 0.05$.

Environmental monitoring

The training locations were subtropical regions in Southeast Queensland, Australia. Ambient temperature (T_a, °C), relative humidity (RH, %), wind speed (km·h^{-1}) and wet bulb globe temperature (WBGT, °C) utilizing the Liljegren's method (Liljegren et al., 2008) were recorded via a portable weather station (Kestrel 5000; Kestrel Instruments, Boothwyn, PA) at 30-s intervals and averaged across 15-min epochs during each pre-season training session, while solar radiation was not considered due to training sessions commencing at or after sunset. The weather station was mounted onto a tripod 1 m above the ground and placed in the same location for each training session. Following the completion of each training session, environmental data were downloaded to a Microsoft Excel spreadsheet for analysis. Data were expressed as mean temperature, humidity, wind speed and WBGT for the session to account for differences in total duration (65–218 min; Table 1).

Statistical analyses

Data for rugby and soccer were directly compared in preliminary full linear modelling analysis for inclusion in GAMs and there were no significant differences between sports. Accordingly, it was appropriate for the data sets to subsequently be combined to determine relationships between fluid intake, BM changes, training performance and environmental conditions via an initial linear regression model followed by a reduced linear model selected using Bayesian Information Criterion (BIC), which was applied to any variable with a significant relationship with fluid intake ($P < 0.05$). Linear modelling required incomplete data points to be removed and therefore total distance and HSR distance included 357 observations and distance per minute included 337 observations, and only within-participant comparisons were undertaken in the statistical analysis. HSR distance was log transformed due to skewness in the observed data. GAMs were then applied to the significant variables from the linear modelling (total distance, m·min^{-1} and HSR distance) with splines (Wood, 2017), allowing relationship modelling of non-linear data to visually interpret the interaction with fluid intake (R.3.4.4 Foundation for Statistical Computing, Vienna, Austria). For GAM figures, the *y* values represent the change in the predicted outcome for any *x* input with respect to the predicted outcome for the average *x* value.

Descriptive statistics for environmental conditions, fluid intake, BM, BM loss, sweat loss, sweat rate and GPS data from rugby and soccer were generated for the experimental period and are presented as mean ± standard deviation (SD) and range (wk 1–11). Analysis between the mean data for each sport across the experimental period was undertaken using *t* test and effects of time between individual training sessions within each sport were conducted via one-way analysis of variance (ANOVA) with repeated measures and Tukey post hoc testing with statistical significance set at $P < 0.05$ (GraphPad Prism 9.1.2, California, USA).

Results

Body mass, fluid intake and sweat rate

Rugby athletes had higher mean BM compared to soccer athletes (rugby 99.5 kg ±14.6 kg vs. soccer 72.6 kg ± 5.6 kg; $P < 0.0001$) and greater mean fluid intake during training sessions throughout the experimental period (1127 mL ± 540 mL vs. 768 mL ± 292 mL; $P < 0.0001$; Table 2). There was no significant difference for mean absolute BM loss between rugby and soccer (1.15 kg ± 0.64 kg vs. 1.07 kg ± 0.62 kg; $P = 0.16$). In contrast, the mean percentage of total BM loss was greater for soccer than rugby athletes during pre-season training (1.46% ± 0.84 vs. 1.15% ± 0.84%; $P < 0.0001$). Similarly, the mean WBSR (L·h^{-1}) during pre-season training were higher in the rugby compared

Table 2. BM, sweat loss and fluid intake data obtained during rugby and soccer training sessions throughout an 11-week pre-season preparation experimental period ($n = 29$ sessions; 357 observations).

	Rugby		Soccer		Combined
	Mean	Range	Mean	Range	Mean
BM, kg	99.5 ± 14.6*	77.9–140.2	72.6 ± 5.7	64.8–84.8	86.4 ± 17.6
BM loss, kg	−1.15 ± 0.64	+0.50 - −3.10	−1.07 ± 0.62	−1.10–2.90	−1.11 ± 0.63
BM loss, %	1.15 ± 0.63*	+0.52 - −3.16	1.46 ± 0.84	1.54–4.39	1.29 ± 0.75
WBSL, L	2.30 ± 0.76*	0.50–4.59	1.85 ± 0.70	−0.35–3.81	2.11 ± 0.78
WBSR, L·h^{-1}	1.16 ± 0.47*	0.18–2.82	0.86 ± 0.42	−0.16–3.49	1.03 ± 0.47
Fluid intake (mL)	1127 ± 540*	113–2586	768 ± 292	69–1859	958 ± 476
Fluid intake (mL·kg)	11.4 ± 5.59*	1.35–27.1	10.5 ± 3.93	0.85–25.7	11.0 ± 4.90
Fluid intake (mL·kg·min^{-1})	0.09 ± 0.05	0.00–0.25	0.08 ± 0.03	0.00–0.21	0.09 ± 0.05

Note: WBSL, whole body sweat loss; WBSR, whole body sweat rate; data are presented as mean (SD) and range, * Denotes significant difference between sports $P < 0.05$.

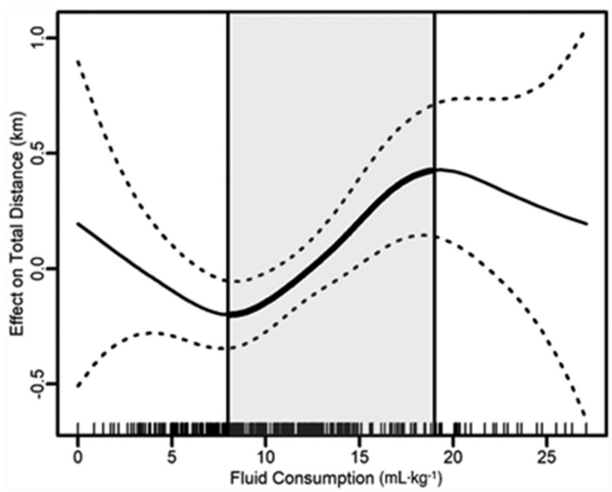

Figure 1. Generalized additive model (GAM) of the relationship between the training sessions total distance and fluid intake during pre-season preparation for rugby and soccer ($P = 0.049$). Grey shaded area shows the section of the curve where a positive relationship between fluid intake and distance covered ensues progressively for every 1 mL·kg^{-1} BM fluid intake to a peak at ~19 mL·kg^{-1} fluid. Minor tick marks on the x-axis represent individual observations contributing to the model ($n = 357$ observations) and dashed lines are 95% confidence limits.

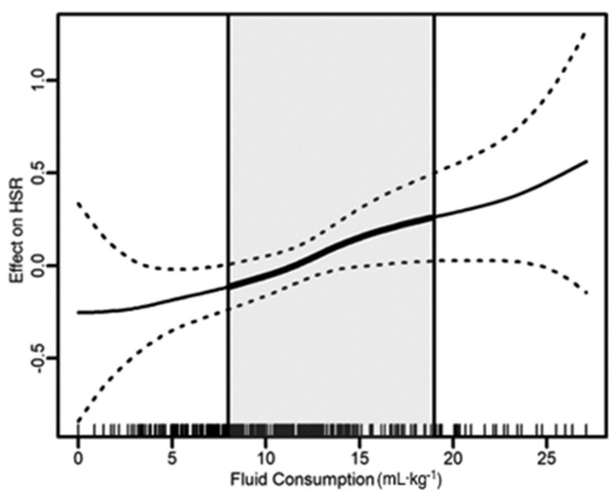

Figure 2. Generalized additive model (GAM) of the relationship between the training sessions relative distance and relationship with fluid intake during pre-season preparation for rugby and soccer ($P = 0.0003$). Grey shaded area shows the section of the curve where a positive relationship between fluid intake and distance covered per minute ensues progressively for every 1 mL·kg^{-1} BM fluid intake to a peak at ~19 mL·kg^{-1} fluid. Minor tick marks on the *x*-axis represent individual observations contributing to the model ($n = 337$ observations) and dashed lines are 95% confidence limits.

to soccer athletes (1.16 L·h^{-1}±0.47 L·h^{-1} vs. 0.86 L·h^{-1}±0.42 L·h^{-1}; $P < 0.0001$). Significant differences in individual sport session by session BM loss, fluid intake and sweat rate were observed across the experimental period (Supplemental Digital Content Figure 1 and 2). Mean number of drinking opportunities during training was 4.30 ± 1.44 and 3.3 ± 1.06, and the mean duration of drinking opportunities was 2.45 ± 0.57 min and 1.78 ± 0.97 min for rugby and soccer, respectively.

Internal and external training load

Mean session RPE during the experimental period was 4.97 ± 1.63 and 7.44 ± 1.16 for soccer and rugby, respectively. Soccer athletes completed more total distance, relative distance (m·min^{-1}) and achieved higher velocities when compared to rugby athletes across the experimental period ($P < 0.0001$; Table 3) but HSR (distance covered above 18 km·h^{-1}) was not different. Mean total session duration across the experimental period was 133 min ±23 min and 127 min ±35 min for soccer and rugby, respectively. Significant differences in individual sport session by session external training load (total distance, relative distance, top speed and HSR) were observed across the experimental period (Supplemental Digital Content Figure 3 and 4).

Generalized additive models

Increasing session duration was closely associated with greater total distance ($P < 0.0001$) but reduced relative distance during training for rugby and soccer sessions ($P = 0.0025$). When session duration was <110 min, total fluid intake had negligible effects on any of the external training load variables. Conversely, for sessions >110 min, when fluid intake reached 10.9 mL·kg^{-1} BM the weighted average for total distance covered during training sessions increased from 7.47 km to 8.06 km (~7.6%; $P = 0.04$). Moreover, every 1 mL·kg^{-1} BM of fluid intake above this threshold was associated with an increase in total distance covered of 0.044 km during training ($P = 0.0003$; Figure 1). In addition, the increase of 1 mL·kg^{-1} BM fluid intake was also associated with an increase of 0.34 m·min^{-1} ($P = 0.01$; Figure 2) and a 4.1% increase in HSR total distance undertaken at >18 km·h^{-1} ($P < 0.0001$; Figure 3). When fluid intake reached a level above ~19 mL·kg^{-1} BM, there were no further improvements in total and relative distance and HSR. There were no significant relationships between fluid intake and maximum velocity during the training sessions. Furthermore, there were no

Table 3. Session training load quantified via GPS during the 11-week experimental period for rugby and soccer athletes ($n = 38$).

	Rugby		Soccer		Combined
	Mean	Range	Mean	Range	Mean
Total distance (km)	6.69 ± 1.48*	2.29–11.1	7.70 ± 1.74	1.61–15.5	7.12 ± 1.65
HSR distance (m)	293 ± 218	0–1040	285 ± 260	0–1704	290 ± 236
Maximum velocity (km·h^{-1})	26.5 ± 2.71*	19.1–33.9	28.2 ± 3.46	18.0–35.1	27.2 ± 3.15
Relative distance (m·min^{-1})	67.9 ± 11.8*	41.2–98.9	79.3 ± 16.0	41.1–121.5	72.5 ± 14.7

Abbreviations: GPS, Global positioning system; HSR, high speed running. Data are presented as mean (SD), * Denotes significant difference between sports $P < 0.05$.

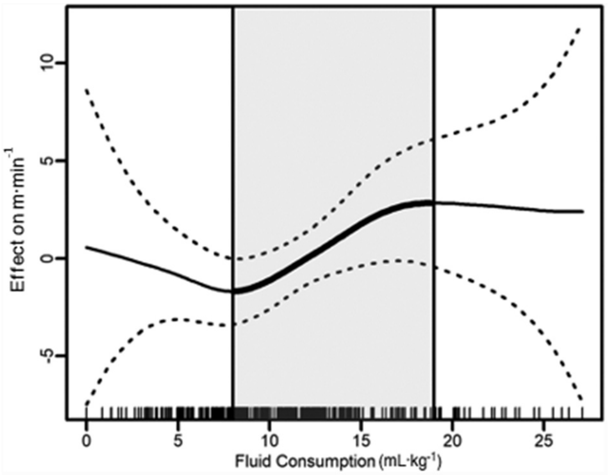

Figure 3. Generalized additive model (GAM) of the relationship between the training sessions HSR distance and relationship with fluid intake during pre-season preparation for rugby and soccer ($P < 0.0001$). Grey shaded area shows the section of the curve where a positive relationship between fluid intake and distance covered per minute ensues progressively for every 1 mL·kg^{-1} BM fluid intake upto ~19 mL·kg^{-1} fluid. Minor tick marks on the *x*-axis represent individual observations contributing to the model ($n = 357$ observations) and dashed lines are 95% confidence limits.

meaningful relationships between environmental variables or internal load and fluid intake during training sessions throughout the experimental period.

Discussion

By interrogating our data with generalized additive modelling, we show for the first time that fluid intake is a strong predictor of work completed in typical outdoor team sport training sessions of prolonged duration (>110 min). Specifically, we report a fluid intake threshold closely associated with improved work capacity during extended training sessions and provide fluid intake targets for outdoor team sport athletes that may augment the total and relative distance and HSR undertaken during training. If favourable chronic adaptations are associated with work performed during outdoor team sport pre-season preparation, optimizing fluid replacement to enhance fluid balance and increase work completed in training should be a priority.

The major finding of the present study was that increased fluid intake between ~10 and 19 mL·kg^{-1} BM was strongly predictive of increased running performance during extended outdoor team sport training sessions. Moreover, this may represent a "performance enhancement range" for fluid intake where lower intakes may be detrimental to maintaining exercise capacity (Nuccio et al., 2017), while larger volumes may have rapidly diminishing returns or potential to decrease work completed in outdoor team sport training sessions (Backes & Fitzgerald, 2016; Dion et al., 2013). Hypohydration induced by heavy sweating during prolonged exercise can result in a decrease in plasma volume, which subsequently reduces stroke volume and cardiac output (Nuccio et al., 2017; Trangmar & González-Alonso, 2017). It seems plausible that greater volumes of fluid ingestion during outdoor team sport training would help maintain plasma volume and may explain the association with improved running performance in the present study. Moreover, the effect is likely to be exacerbated in the warm/humid conditions of our study when blood flow is needed for competing requirements of muscle contraction and skin blood flow for cooling (Nuccio et al., 2017, Montain et al., 1995). Given that for every 1 mL·kg^{-1} BM of fluid intake within this range there was an associated and predictable increase in GPS metrics the implication is that the top of the range would be a "target" and most beneficial for outdoor team sport athletes during extensive training sessions, but further work is necessary to corroborate this as a recommendation. Our study is limited to semi-professional rugby and soccer athletes at specific geographical locations and environmental conditions but could have broader applications to be implemented in other locations and team sport settings. Indeed, there are currently no specific team sport fluid ingestion guidelines, and the present study may serve as a basis for recommendations until future large-scale intervention studies and/or meta-analyses are undertaken with team sport athletes.

Holland and colleagues (Holland et al., 2017) have previously undertaken a meta-analysis on the influence of fluid intake on endurance cycling performance and suggested that for a 70-kg athlete an estimated range of~10–19 mL·kg^{-1} BM fluid intake for exercise approaching or greater than 2 h duration should result in 2–3% improvement in performance. Our findings in the outdoor team sport training context show increases of ~4–7% in key metrics of running performance during training. However, only a modest number of observations in the present study show athletes ingesting fluid at or above 19 mL·kg^{-1} BM under ad libitum conditions. Moreover, the mean fluid intakes for rugby and soccer were at the low end of the range (10–11 mL·kg^{-1} BM) with substantial individual variation within athlete cohorts. Indeed, to achieve mean fluid intakes that equate to the upper range (~19 mL·kg^{-1} BM) would require a ~40–45% increase in fluid ingestion during training for many of the rugby and soccer athletes in our study. Whether it is plausible to achieve higher fluid ingestion through specific hydration strategies in outdoor team sports is unclear. Indeed, the repeated high-intensity efforts and physical collisions in outdoor team sports may mean higher fluid intakes lead to gastrointestinal discomfort. While some aspects of gut tolerance may be trainable the discomfort may mitigate the potential benefit of maintaining fluid balance on exercise performance, at least for some athletes (Lambert et al., 2008). Backes and Fitzgerald (Backes & Fitzgerald, 2016) have previously shown exercise performance is reduced when planned fluid intake rate is higher than voluntary fluid intake rate and suggest increased gastric emptying and diversion of blood flow to the gut and away from the working muscles may also reduce exercise capacity. Nonetheless, it may be reasonable to suggest that outdoor team sport athletes should attempt to ingest the maximum tolerable fluid intake within the proposed range to enhance exercise capacity during prolonged training sessions.

The beneficial effect of increasing fluid intake on work performed in training in the present study is similar to Edwards and co-workers (Edwards et al., 2007) who showed immediate post-match soccer performance quantified as distance covered during the Yo-Yo intermittent recovery test (level 2) was improved when fluid intake was permitted during match play.

Additionally, McGregor and colleagues (McGregor et al., 1999) reported a negative effect on mean sprint time in soccer players undertaking the Loughborough intermittent shuttle test when fluid intake was restricted. Our novel data advance our current understanding of the relationship between fluid intake and performance during outdoor team sport training sessions regularly undertaken during pre-season preparation. However, there was no relationship between fluid intake and athletes' session RPE throughout the experimental period for either sport in the current study. This is in contrast to some previous studies showing a significant increase in RPE when comparing ad libitum versus no fluid intake in female and male soccer and basketball athletes completing training sessions of ~90 minutes duration (Ali & Williams, 2013; Ali et al., 2011; Carvalho et al., 2011; McGregor et al., 1999; Owen et al., 2013). We report no effect of fluid intake on session RPE, but the intra-individual variation in fluid intake in the present study may have been insufficient to induce changes in perceived effort or how "hard" a training session is perceived and that only total fluid restriction generates this effect.

The fluid intakes characterized in the present study are similar to previously published data on the fluid balance of professional soccer athletes during training sessions (Duffield et al., 2012; R. J. Maughan et al., 2004; Shirreffs et al., 2005). Duffield and colleagues (Duffield et al., 2012) have shown that BM losses are not matched with fluid intake during training when athletes were given access to fluid throughout training. Moreover, sweat rates during outdoor team sport training have been shown to be dependent on the intensity of the session but ranged between 0.6 and 2 $L{\cdot}h^{-1}$, with associated BM loss of 1.1–1.2 kg (Duffield et al., 2012; R. J. Maughan et al., 2004; Rollo et al., 2021; Shirreffs et al., 2005). Similarly, other studies have shown rugby union athletes are unable to maintain fluid balance during training sessions with mean BM loss of ~1 kg and ~1.4–1.7 $L{\cdot}h^{-1}$ sweat rates reported for professional athletes (Borges et al., 2017; Cosgrove et al., 2014; Jones et al., 2015; Love et al., 2018). Interestingly, participants in the current study consumed less fluid compared to previous studies undertaken in warmer environments (R. J. Maughan et al., 2004; Shirreffs et al., 2005) but more fluid than other studies conducted in colder climates (R. Maughan et al., 2005). While not unexpected, the comparison between studies (R. J. Maughan et al., 2004; R. Maughan et al., 2005; Shirreffs et al., 2005) provides support for environmental conditions as a determining factor in fluid consumption during outdoor team sport training when athletes have ad libitum access to fluid during breaks, and train under comparable session intensity and durations. However, the range of environmental conditions in the present study may not have been enough to elucidate the impact or association of different ambient temperature and relative humidity on fluid intakes. Regardless, the data provide further characterization of fluid intake and BM loss from a large number of observations in rugby union and soccer during the preparatory phase in outdoor team sports.

A limitation of the present study is that the hydration status at commencement of training sessions was not determined and previous studies indicate that some outdoor team sport athletes may regularly present to training sessions hypohydrated (Chapelle et al., 2020; Cosgrove et al., 2014). In such cases, the inability to match fluid intake to sweat rate during training might be expected to exacerbate decreases in the work completed and further reduce quality of training. We cannot rule out that hydration status at commencement of training did not affect some data within the statistical analysis, but a strength of our analysis was the large dataset and within participant design to reduce the effect of confounding variables. Nonetheless, in circumstances where athletes begin training hypohydrated the need to achieve a recommended fluid intake is likely greater for relative performance capacity to be maintained. However, further work is needed to determine the implications of outdoor team sport athletes commencing training in a hypohydrated versus euhydrated state and how this may affect fluid intake behaviours and training performance.

Conclusion

In conclusion, our data are the first to show the effects of fluid intake on work completed during field-based outdoor team sport training. We have demonstrated lower and upper limits of fluid intake that are strong predictors of improved running performance during extended sessions beyond which work completed may be impaired or diminished. It appears that most outdoor team sport athletes fail to match fluid loss during training, and we provide a practical ingestion range closely associated with better physical performance. Improved hydration practices during training sessions should be beneficial to the quality of training throughout pre-season preparation, which may translate to greater physical performance capacity in outdoor team sport competition.

Disclosure statement

No potential conflict of interest was reported by the authors.

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