Hydration of male surfers during training in a subtropical environment

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Abstract

Background*:* To date, limited research has been conducted on hydration in surfers and no recommendations could be found regarding optimal hydration practices in surfers. This makes it difficult for dietitians and surf coaches to give evidence-based advice to surfers regarding optimal hydration practices. In order give recommendations to surfers concerning optimal hydration, research is needed to investigate the degree of dehydration at which surfing performance and the possible factors influencing surfing performance are impaired. Further, the current hydration behaviour of surfers needs to be investigated by means of objective measurements. ***Aim****:* To gain insight into hydration in surfers and the possible implications on surfing performance. ***Method****:* The hydration status before surfing was measured by means of urine specific gravity ($U_{sg)}$, the sweat rates were investigated by means of body mass difference after compared to before surfing and hydration behaviour was assessed using a questionnaire asking for the usual drinking behaviour of the participants before and after surfing and the perceived importance of hydration for performance. The interrelationships between hydration behaviour and sweat rate and hydration behaviour and hydration status before surfing were determined by means of Spearman correlations and student t-tests using SPSS 20. Moreover, a literature study was conducted to assess the influence of dehydration on surfing performance and the actual amount of fluid intake in surfers. ***Results:*** Twenty-two male surfers were included in the analysis. As indicated by a U_{sg} greater than 1.020 g/ml, 45% of the participants were dehydrated prior to surfing. The average U_{sg} of all samples was 1.019 g/ml. The mean sweat rate was -0.48 litres per hour resulting in a mean body mass loss of -0.6% per hour. When asked about their hydration behaviour prior to surfing 37% of the participants indicated that they drink extra fluids only “sometimes” or “never” before surfing. Eighteen per cent of the surfers indicated that they “always” ingest extra fluid before surfing and 45% “mostly” ingest extra fluid. In contrast, 77% indicated that they “always” or “mostly” drank additional fluids after surfing and 23% “sometimes” consumed extra fluid. No relationship could be found between reported drinking behaviour and U_{sg} or sweat rate ($P>0.05$). Participants rated the importance of hydration with a mean score of 8.1 out of 10. No significant correlation was found between U_{sg} and hydration-importance-rating ($P>0.05$). ***Conclusion:*** There is a clear discrepancy between the knowledge about the importance of hydration and the reported drinking behaviour and measured hydration status. Sweat losses during surfing in combination with hypohydration before the start of the surfing session or a longer duration of the surfing session can lead to a significant level of dehydration to impair surfing performance. The results show that hydration guidance in surfers should be individualized and based on the individual sweat rate of the surfer while the importance of hydration before surfing should be stressed.

SAMENVATTING

Aanleiding**:* Onderzoek op het gebied van hydratatie bij surfers is schaars en er konden geen aanbevelingen gevonden worden met betrekking tot de ideale vochtinname voor surfers. Dit bemoeilijkt het voor diëtisten en surf coaches om goed onderbouwd advies te geven aan surfers met betrekking tot optimale vochtinname. Om aanbevelingen te geven aan surfers voor de ideale vochtinname is onderzoek nodig naar de gradatie van dehydratatie waarbij een nadelig effect op de prestatie te verwachten is. Verder is objectief onderzoek nodig naar het huidige gedrag van surfers met betrekking tot vochtinname. ***Doel**:* Inzicht te krijgen in de hydratatie van surfers en de mogelijke effecten op de surf prestatie. ***Methode**:* De hydratatie status aan het begin van de surf sessie werd gemeten aan de hand van de relatieve dichtheid van urine. De zweet productie werd geschat door middel van gewichtsverlies. Het vochtinname gedrag werd onderzocht aan de hand van een vragenlijst over de gebruikelijke vochtinname voor en na het surfen en over het ervaren belang van hydratatie. De verbanden tussen vochtinname gedrag en zweet productie en vochtinname gedrag en hydratatie status voor het surfen zijn bepaald door middel van Spearman correlaties en t-toetsen voor onafhankelijke steekproven in SPSS 20. Daarnaast werd aan de hand van literatuuronderzoek geëvalueerd in hoeverre dehydratatie van invloed is op de surf prestatie en de kwantitatieve vochtinname van surfers. ***Resultaten: Tweeëntwintig mannelijke surfers zijn meegenomen in de analyse. Gebaseerd op de afkapwaarde van 1.020 g/ml voor de relatieve dichtheid van de urine waren 45% van de deelnemers gedehydreerd (>1.020g/ml) aan het begin van de surf sessie. De gemiddelde relatieve dichtheid van de urine was 1.019g/ml. De gemiddelde zweet productie was -0.48 liter per uur, resulterend in een gemiddeld percentueel gewichtsverlies van -0.6% per uur. Daarnaast gaven 37% van de deelnemers aan alleen “soms” of “nooit” extra vocht tot zich te nemen voor het surfen. Achttien procent van de surfers gaven aan “altijd” te drinken voor het surfen en 45% nemen “meestal” extra vocht tot zich. Daarentegen gaven 77% aan “altijd” of “meestal” te drinken na het surfen en 23% namen “soms” extra vocht tot zich. Geen verband werd gevonden tussen het gerapporteerde vochtinname gedrag en de hydratatie status voor het surfen of de zweet productie (P>0.05). De deelnemers beoordeelden het belang van hydratatie met een gemiddelde score van 8.1 van 10. Het verband tussen het belang van hydratatie en hydratatie status voor het surfen was niet significant (P>0.05). ***Conclusie:*** Er is een duidelijke discrepantie tussen kennis over het belang van hydratatie en het gerapporteerde vochtinname gedrag. In combinatie met dehydratatie voor het surfen of een langere surf sessie kan zweet verlies tijdens het surfen leiden tot een significant vochtverlies met negatieve gevolgen voor de prestatie. De resultaten laten zien dat adviezen voor surfers met betrekking tot vochtinname gebaseerd moeten worden op de individuele zweet productie en gewoontes van de surfers, waarbij hydratatie voor het surfen een belangrijke focus punt is.

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1. INTRODUCTION

Over the last decades the popularity of surfing has increased rapidly at both, the recreational and competitive level (Mendez-Villanueva & Bishop, 2005). In Australia more than 2.5 million people enjoy surfing and the sport's popularity exceeds that of other popular sports such as cricket, netball and basketball (Meir, Zhou, Gilleard & Coutts, 2011).

Surfing can be described as a highly demanding sport, requiring muscular endurance, power of the upper torso, cardiorespiratory endurance and recovery abilities as well as excellent mental and cognitive activity (Mendez-Villanueva & Bishop, 2005; Farley, Harris & Kilding, 2012a). Regarding the highly demanding nature of surfing and taking into consideration that a common surf practice can be several hours in duration (Felder, Burke, Lowdon, Cameron-Smith & Collier, 1998; Meir, Lowdon & Davie, 1991; Mendez-Villanueva, Bishop & Hamer, 2006) adequate hydration might be impaired.

The current body of knowledge indicates that sweat loss during a 100-minutes surfing session can be great enough to impair surfing performance and factors that possibly influence surfing performance, such as cognitive function and muscular endurance (Carrasco, 2008). No existing study could be found investigating the hydration status prior to a surfing session. However, research on athletes in other disciplines than surfing shows that athletes might fail to be sufficiently hydrated at the start of a competition or training (Stover et al., 2006; Finn & Wood, 2004). According to a retrospective survey, including 685 Australian surfers, only 21.4% of the surfers "always" drank additional fluids before going into the water, in order to promote adequate hydration, whereas 24.8% indicated that they "never" drank additional fluids prior to surfing (Meir et al., 2011). This study indicates that hydration practices in surfers, similar to athletes in other disciplines, might not be optimal. Though, the abovementioned study underlies the limitations of a retrospective study of self-reported fluid intake and therefore a study using objective measurements of hydration status is needed in order to get insight into the actual hydration behaviour of surfers.

To date no recommendations could be found regarding optimal hydration practices in surfers. This makes it difficult for dietitians and surf coaches to give evidence-based advice to surfers regarding optimal hydration practices. In order to give recommendations to surfers concerning optimal hydration to promote superior surfing performance, research is needed to investigate the degree of dehydration at which surfing performance and the possible factors influencing surfing performance are impaired. Further, the current hydration behaviour of surfers needs to be investigated by means of objective measurements.

The purpose of this study is to use literature and field research methods to investigate the degree of dehydration possibly influencing surfing performance, hydration status prior to surfing practice, sweat loss during a common surfing practice and current hydration behaviour of surfers, as well as the relation between hydration behaviour and sweat loss and the relation between hydration behaviour and hydration status prior to exercise.

More specifically, the following research questions were addressed:

Main question
To what extent are surfers hydrated and what are the possible implications on surfing performance?

Literature study

1. What is the influence of dehydration on surfing performance?
    a. What are the physical demands of surfing based on the activity profile of surfing?
    b. How does hypohydration affect the different factors that influence surfing performance? (E.g. aerobic performance, anaerobic performance, cognitive function)?
2. What is known about the amount of fluid that surfers ingest on a training or competition day?

Field study

The field study was performed in South East Queensland and the northern region of New South Wales, which represents a region with subtropical climate (Stern, de Hoedt & Ernst, 2000). For surfing in this region the following questions have been examined:

1. What is the hydration status of male surfers prior to a common surfing training?
2. What is the sweat rate of male surfers during a common surfing session?
3. What is the hydration behaviour of male surfers before and after surfing?
4. How does the hydration behaviour of male surfers relate to their hydration status before training?
5. How does the hydration behaviour of male relate to their sweat rate during a common surfing session?
6. How important do male surfers of this region rate hydration for surfing performance, and does this relate to hydration status before surfing?

This research will allow sports scientists, dietitians and coaches to get insight into the effects of dehydration on surfing performance and the hydration practices of surfers in a subtropical environment. Further, these insights will help to form recommendations to optimize fluid intake in surfers which will support dietitians and coaches in giving practical advice concerning optimal hydration in surfers. The practical recommendations for optimal hydration in surfers based on the main findings of this study are attached in Appendix 5.

2. METHOD

In order to answer the main question "To what extent are surfers hydrated and what are the possible implications on surfing performance?", a literature study and a field study were conducted.

2.1. Literature Study

In order to get insight into the role of hydration in surfing performance and the hydration behaviour of surfers, a literature study was conducted. For this purpose the databases Google Scholar, CINAHL, MEDLINE and SPORTdiscuss were searched, as well as the libraries of The University of Queensland and The Hague University of Applied Sciences. The keywords used to retrieve the articles of interest were as follows: 'activity profile', 'aerobic performance', 'anaerobic performance', 'athletes', 'cognitive function', 'dehydration', 'exercise', 'fluid intake', 'hydration', 'hydration status', hypohydration', 'nutrition', 'physical demands', 'physical requirements', 'surfing', 'surfers'. These terms were either used alone or in combination during the search process. Further, relevant references cited in articles were looked up. Articles were selected taking into account relevance, year of publication and quality of evidence according to the Oxford levels of evidence (Centre for Evidence-Based Medicine, 2009). Preferably recent articles, published within the past 15 years, were used and articles rated with a level of evidence '2' or higher.

2.2. Field Study

In order to investigate the hydration status prior to surfing practice, sweat loss during a common surfing practice and current hydration behaviour of surfers in a subtropical environment, a field study was conducted collecting quantitative data.

2.2.1. Ethics Approval

Prior to commencement, the study has been cleared in accordance with the ethical review guidelines at The University of Queensland. All participants were handed an information sheet outlining the aims, methods, risks and benefits of the study (see Appendix 1) and were then free to decide whether to participate in the study or not. Prior to initiating data collection written informed consent was obtained from each participant (see Appendix 2).

2.2.2. Participants

The participants were recruited during the months November and December in the coastal regions of South East Queensland and the northern coastal regions of New South Wales. According to a classification of Australian climates, the climate of these regions is classified as subtropical (Stern, de Hoedt & Ernst, 2000). The participants were contacted via social media pages and websites of surf clubs and surf communities that were situated in South East Queensland and the northern part of New South Wales (such as the Facebook page of the 'Brisbane Surf Club', the 'Brisbane Surfing Page' or 'Burleigh Boardriders'). An invitation was placed on the websites or in the Facebook groups informing potential participants about the background, purpose and protocol of the study. Flyers were posted in local surf shops and surf live saving clubs and surfers were recruited in person at different beaches in South East Queensland and the northern part of New South Wales. Because participants were randomly contacted at different beaches, surf shops, local surf clubs and via surfing groups in South East Queensland and the northern part of New South Wales, they are expected to be a representative sample for male surfers in South East Queensland and the northern part of New South Wales. It can be assumed that the data is also representative for all other surfers training under similar environmental conditions (including air and water temperature and type of wetsuit).

Exclusion criteria were female gender, age below 18, age above 50 and use of any medications that alter fluid or electrolyte balance (e.g. diuretic medication). In this study females were excluded, because the menstrual cycle and the use of contraceptives are known to influence water retention and kidney function, which makes it difficult to measure the hydration status in the female population (Benton & Young, 2015). All male surfers aged between 18 and 50 willing to participate were included without asking specific questions concerning the subjects' health status, assuming that this sport can only be performed by healthy subjects. The upper limit of 50 years was chosen because of the possible effects of age on sweat rate (Inbar, Morris, Epstein & Gass, 2004). Further, participants of all levels of surfing were included.

2.2.3. Description of Measurements Used

Hydration status prior to the surfing session

The hydration status prior to training was assessed by means of Urine specific gravity (U_{sg}) in order to investigate whether the surfers are well hydrated or dehydrated prior to training. To assess hydration status the participants were asked to void urine into a 50 ml sterile container before the start of their surfing session. To analyse $U_{sg,}$ a refractometer (RHC-200ATC clinical refractometer) was used at the beach and a cut-off value of 1.020 g/ml was used to classify the participants as well hydrated (U_{sg} ≤ 1.020 g/ml) or dehydrated (U_{sg} > 1.020 g/ml). At the start of each testing day the refractometer was calibrated using distilled water.

Measurement of U_{sg} is generally accepted as an appropriate screening tool for classification of hydration status with the common cut-off value of 1.020 g/ml classifying individuals as well hydrated or dehydrated (Casa et al., 2000; Armstrong et al., 2010; Opplinger & Bartok, 2002). Research shows that there is no significant difference in U_{sg} for location, age, time of day or exercise habits, whereas there is a significant difference in U_{sg} for gender (Stover et al., 2006). Therefore U_{sg} can be used as a valid means for investigating hydration status in male surfers, irrespective of location, age, time of the day and exercise habits.

Sweat rate

The sweat rate during training was estimated by means of body mass change (ΔBM) after as compared to before a surfing training session. In order to calculate the sweat rate, the duration of the surfing session was recorded. The measurement of ΔBM is a commonly used, reliable and accurate method of estimating change in body water within a day (Cheuvront, Carter, Montain & Sawka, 2004; Baker, Lang & Larry Kenney, 2009).

Prior to being weighed, participants were asked to completely empty their bladder. All participants were weighed in their dry underwear or board shorts and wetted hair on a digital weight scale (Tanita HD-382) with a precision of 0.1kg. After completion of the training session participants were asked to towel dry thoroughly, change and were weighed again on the same scale, at the same place, in their dry underwear or board shorts and wet hair. No correction was made for respiratory water loss or substrate metabolism as the error is expected to be small during a training session of less than four hours (Armstrong, 2005; Maughan & Shirreffs, 2010).

Hydration behaviour

After completing the surfing session the surfers were asked to complete a questionnaire (see Appendix 3), in order to get insight into their hydration behaviour. To ensure that the questionnaire is unequivocal, it was tested beforehand in a small group of surfers (n=7) and minor amendments were made to improve the understanding of the questions.

Characteristics of the surfers
Using the same questionnaire, data about age and height of the surfers was collected, in order to determine the characteristics of the surfers. Further, the participants were asked their surfing experience (in years), if they take part in competitions, in which level of competitions they take part and how much time (in minutes) they usually spend in the water per session, in order to get insight in their usual surfing habits.

Environmental conditions
To countercheck the influence of environmental conditions, the air temperature and water temperature, obtained from the website Magicseaweed, were registered during the training days (Magicseaweed, n.d.). Also, the type of wetsuit the participants wore was registered.

2.2.4. Statistical Analyses

All statistical analyses were performed using IBM SPSS statistics (version 20) and statistical significance was set at $P<0.05$.

Hydration status
In order to analyse hydration status the common cut-off value of 1.020 g/ml (Casa et al., 2000; Armstrong et al., 2010; Opplinger & Bartok, 2002) was used to classify individuals as hydrated ($U_{sg} \leq 1.020$ g/ml) or dehydrated ($U_{sg} > 1.020$ g/ml). The data is presented as percentages of participants who were hydrated or dehydrated at the start of their surfing session.

Body mass measurements
The data obtained from body mass measurements is presented as mean sweat rate (sweat loss in litres per hour) ± standard deviation (SD) as well as mean percentage of body mass loss ± SD. Further, the significance of the difference in mean body mass before training and mean body mass after training was assessed by performing a paired t-test.

Hydration behaviour
The results of the first two questions on hydration behaviour “Do you normally ingest extra fluid before surfing in order to stay well hydrated? – never / sometimes / mostly / always” and “Do you normally ingest extra fluid after surfing in order to stay well hydrated? – never / sometimes / mostly / always” were analysed as percentages of participants who answered never, sometimes, mostly and always, respectively.

Further, the relationship between fluid intake before surfing and hydration status before training was researched by means of a student t-test, analysing whether there is a significant difference between mean U_{sg} of participants who “always” or “mostly” ingest fluid before surfing and participants who “never” or “sometimes” ingest fluid before surfing.

The relationship of sweat rate and information on fluid ingestion after surfing was assessed by means of a student t-test analysing whether there is a significant difference in mean sweat rate of participants who “always” or “mostly” ingest fluid after surfing and participants who “never” or “sometimes” ingest fluid after surfing.

Moreover, the relationship between hydration status before training and information on usual fluid ingestion after training was investigated by performing a student t-test analysing whether there is a significant difference in mean U_{sg} of participants who “always” or “mostly” ingest fluid after surfing and participants who “never” or “sometimes” ingest fluid after surfing.

Lastly, the results of the third question “On a scale from 1 (not important) to 10 (very important), how important do you think hydration is for surfing performance?” are presented as mean score ± SD. To see if there is a relationship between the rating of importance and the hydration status before surfing a Spearman correlation was used with the following categories for U_{sg}, based on the classification according to Armstrong et al. (2010): 1= "extremely hyperhydrated" (<1.012), 2= "Slightly hyperhydrated" (1.012–1.014), 3= "well hydrated" (1.015-1.017), 4= "euhydrated" (1.018-1.020), 5= "Slightly dehydrated" (1.021-1.024), 6="very dehydrated" (1.025-1.027), 7="extremely dehydrated" (>1.027).

Characteristics of the surfers

The data about age, height, surfing experience, time usually spent on the water obtained from the section 'characteristics of the surfers' of the questionnaire was analysed and presented as means ± SD. The data on level of competitions is presented as percentages of participants.

Environmental conditions

Data about environmental conditions and wetsuits is presented as mean water and air temperature ± SD and number of participants wearing a steamer wetsuit, short wetsuit or board shorts/swimming trunks. Further a Pearson correlation was performed to assess whether the time participants stayed on the water during the testing day correlates with the indicated time they usually spend on the water and the mean time spent on the water during the testing day was compared to the reported average duration of a surfing session.

3. LITERATURE REVIEW

The following literature review investigates the influence of dehydration on surfing performance and the possible factors influencing surfing performance. Also, the existing literature was searched for studies assessing the amount of fluid intake of surfers.

3.1. Influence of Dehydration on Surfing Performance

In order to investigate the possible influence of dehydration on surfing performance, it is important to firstly analyse which physical and mental abilities may have an impact on surfing performance. It can then be investigated whether these physical and mental abilities are likely to be influenced by dehydration or not.

3.1.1. Physical and Mental Demands of Surfing

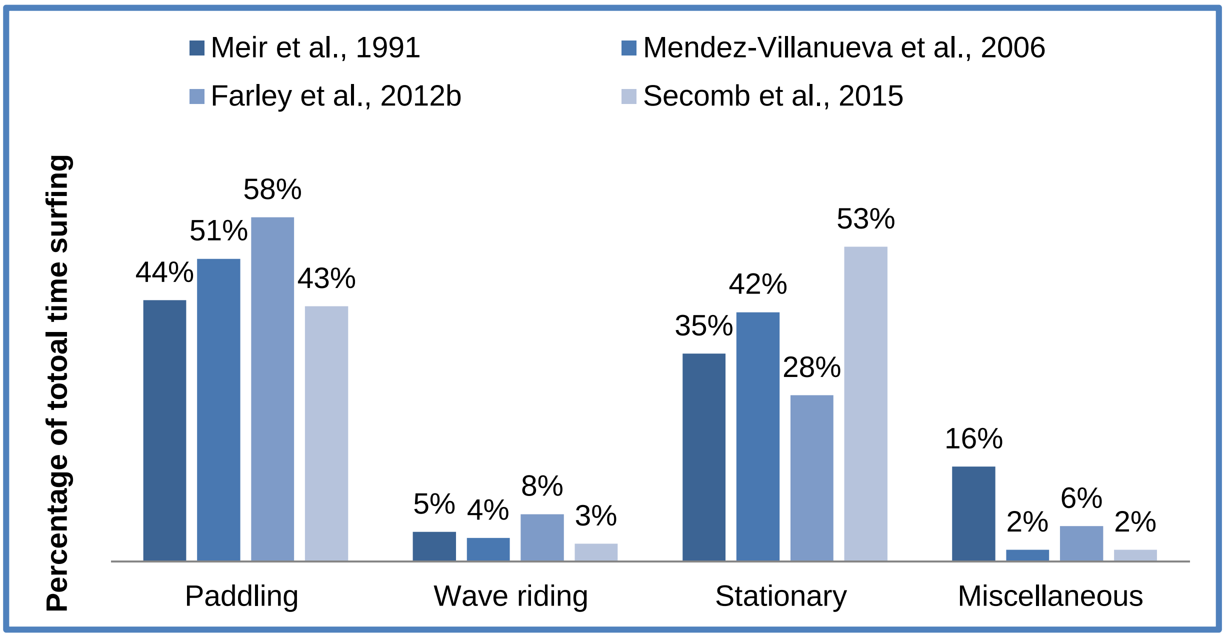
The physical demands of surfing will be studied by analysing the activity profile of surfing and by researching the physical and mental abilities that might influence surfing performance.

Activity profile of surfing
Before entering the water, the surfer usually observes the conditions first, in order to gain information about wave size, time period between the waves, breaking pattern of the waves and currents, such as rip currents that flow back to the sea and which can be used in the surfer's advantage when paddling out (Young, 1988). The process of surfing starts with the surfer paddling in the prone position on the board from the beach to the 'take-off area', where the waves break. When paddling out, timing is important and bouts of faster paddling might be required to pass waves that are about to break in front of the surfer. Sometimes the surfer needs to duck with his board under broken waves or waves that are about to break. Once the take-off area is reached and a suitable wave approaches, powerful paddling is required, in order to catch the wave. When the wave has been caught, the surfer needs to stand up quickly and can then choose to perform a variation of manoeuvres on the unbroken wave. This process is repeated several times during a surfing session (Mendez-Villanueva & Bishop, 2005; Young, 1988) which could take in between less than half an hour up to several hours (Meir et al., 1991).

Studies have been conducted to investigate the time-motion analysis of surfers during competition (Mendez-Villanueva et al., 2006; Farley, Harris & Kilding, 2012b), recreation (Meir et al.,1991) and training (Secomb, Sheppard & Dascombe, 2015).

On average the surfers spent 43 to 58% paddling, 28 to 53% stationary, 3 to 8% wave riding and 2-16% of the total time miscellaneous, which includes other activities such as ducking the board under waves and recovering and getting back on the board after falling (see Figure 1). The differences between the reported percentages of the abovementioned studies might be due to variations in wave conditions between the trials, and the competitive or recreational nature of the session. Also, the different methodologies applied for the time-motion analyses may explain the differences: Meir et al. (1991) and Mendez-Villanueva et al. (2006) only used individual video tracking, whereas the more recent studies of Farley et al. (2012b) and Secomb et al. (2015) make use of GPS tracking in combination with video recording, which might deliver more accurate results. Further, the definitions of the various surfing activities were slightly different in the studies, although all studies based their criteria on those used in the study by Meir et al. (1991). However, all studies show that the greatest amount of time during a surfing session is spent paddling and stationary whereas actual wave riding accounts for the least amount of time. Paddling can be further divided into sprint paddling for waves, general paddling, and paddling to return to the line-up (Secomb, et al., 2015). Considering that the greatest amount of time during surfing is spent paddling, it seems obvious to conclude that general upper body aerobic endurance is an important component for surfing performance. Though, other factors, such as sprint paddling to catch waves, upper body power to stand up quickly on the board and lower body strength to perform manoeuvres on the unbroken section of the wave might be equally important physical performance characteristics to surfing performance.

Figure 1 Time motion analysis of surfers



Influence of certain physical and mental characteristics on surfing performance
Few studies have been conducted to investigate the contribution of physical performance characteristics to surfing performance.

A study conducted by Mendez-Villanueva, et al. (2005) investigated whether a link exists between upper-body aerobic fitness characteristics and surfing performance. Ranking of the surfers according to the scores achieved during the competitive season was used as a measurement for surfing performance. The participants were divided into a group of six European-level surfers and a group of seven regional level surfers, while European-level surfers were considered the better surfers. All tests were performed on a modified kayak ergometer which allowed the participants to adopt a prone position similar to the actual surfing paddling position and perform a simulated paddling exercise. While Mendez-Villanueva et al. (2005) observed no significant difference (P>0.05) in peak oxygen uptake, aerobic peak power output and exercise intensity corresponding to a blood lactate concentration of 4 mmol/L (which is used as an indicator for endurance performance and intermittent exercise performance) were significantly higher (P=0.04; P=0.02) in the European level surfers compared to the regional-level surfers and showed a significant correlation with season ranking (r=-0.67, P=0.01; r=-0.57, P=0.04). The researchers therefore concluded that surfers who perform better (higher ranked surfers) have higher upper body aerobic fitness scores. However, the results of the study of Mendez-Villanueva et al. (2005) need to be interpreted with caution, as ranking of the surfers and classification into European and regional-level surfers was used to measure surfing performance without observing their actual surfing ability and because of the relatively low number of participants.

The ability to produce a greater aerobic peak power output at the end of an incremental exercise test with the same peak oxygen uptake might be associated with a higher lactate threshold. In runners lactate threshold has been found to be a better predictor for endurance than maximal oxygen uptake alone (Bassett & Howley, 2000). In line with the abovementioned findings Loveless and Minahan (2010) observed no difference ($P>0.05$) between junior recreational and competitive surfers for peak oxygen uptake during an incremental paddling test on a swim bench ergometer, whereas blood lactate concentration was found to be significantly greater ($P=0.04$) in recreational compared to competitive surfers. Overall, the abovementioned studies indicate that upper body aerobic fitness might play an important role in surfing performance.

Another study conducted by Tran et al. (2015) investigated whether there is a difference in performance outcomes between 16 non-selected and 16 selected male competitive surfers for the Australian national junior team. The researchers found significant ($P<0.05$) differences between the two groups in time to 5-, 10- and 15-metre sprint paddle, peak velocity in sprint paddling, 400-metre endurance paddle time, average endurance paddling velocity, relative vertical-jump force normalized to body mass, vertical-jump height and lower body strength when normalized to body mass.

Although it is uncertain whether the results of the junior surfers are also representative for the adult population, this study is in line with the studies by Mendez-Villanueva et al. (2005) and Loveless and Minahan (2010) which indicate that superior aerobic endurance might be an indicator for surfing performance. Further, this study shows that besides aerobic endurance, different performance outcomes, such as time to 15-metres sprint paddle, sprint paddling velocity, vertical-jump peak force and vertical-jump height, might influence surfing performance. Moreover, this study shows that relative lower body maximum strength might be an indicator for superior surfing performance.

Carrasco (2008) investigated the relationship between different parameters of cognitive function and actual surfing performance in 12 Australian national- and international-level surfers. All surfers were judged on their surfing performance by the same three experienced judges according to the criteria of the ASP world tour. Short term memory was assessed by means of a short-term memory test, working memory and information processing were measured by means of a paced serial addition test and attention, visuomotor skills and visual acuity were evaluated using a trail making test. Carrasco (2008) found a moderate relationship between short-term memory and surfing performance score ($r=0.63$, $P<0.05$), a good relationship between paced serial addition performance and surfing performance ($r=0.74$, $P<0.05$) and a moderate relationship between trail making ability and surfing performance ($r=0.58$; $P<0.05$). A limitation of this study is the small number of participants ($n=12$). Despite the fact that correlation does not imply causation, this study indicates that cognitive function might be linked to surfing performance as a moderate to good relationship between all researched domains of cognitive function and surfing performance was found. Information processing and working memory showed the strongest correlation with surfing performance. Looking at the activity profile of surfing it stands to reason that the ability to respond to environmental cues such as changing wave conditions and currents is linked to surfing performance as it helps the surfer with paddling out, identifying superior waves and the right timing of manoeuvres on the wave. The ability to identify hazards, such as currents, and respond to them in a correct way is also an important safety factor.

Overall, the abovementioned studies show that surfing demands upper body aerobic endurance as well as upper and lower body muscular strength, jumping ability and excellent cognitive function (especially working memory and information processing). Linking the results on physical characteristics to the activity profile of surfing, upper body aerobic endurance is likely to be important for general paddling, which accounts for the greatest amount of time during surfing, while upper body muscular strength is expected to be required for sprint paddling and ducking the board under waves. If upper body muscular strength and thus sprint paddling performance is impaired, the surfer's ability to catch waves will decrease. Lower body muscular strength and jumping ability are most likely required when performing manoeuvres on the wave. Although actual wave-riding accounts for the least amount of time during surfing, professional surfers will be judged on their wave riding ability (Association of Surfing Professionals, 2015). This shows that factors influencing wave riding performance, such as lower body muscular strength and jumping ability are as important as aerobic endurance for surfing performance. Lastly, excellent cognitive ability is likely to be required to identify superior waves as well as to identify hazards such as currents and rocky areas and to act accordingly (Young, 1988). In the following chapter the possible influence of dehydration on those factors will be analysed.

3.1.2. Influence of Dehydration on Factors that Influence Surfing Performance

The previous chapter investigated the physical characteristics that are likely to influence surfing performance. It was concluded that surfing demands upper body aerobic endurance, upper and lower body muscular strength, jumping ability and excellent cognitive performance. Based on these results, this chapter will examine the influence of hydration on those factors.

Upper body aerobic endurance
As upper body aerobic performance is expected to be an important fitness requirement for paddling performance and is therefore supposed to influence surfing performance the following paragraph examines the effect of dehydration on upper body aerobic performance.

The effect of dehydration on aerobic performance has been studied extensively. Cheuvront, Carter and Sawka (2003) have undertaken a review including 13 studies which examined the effects of dehydration on endurance performance. He concluded that in hot environments (> 30°C) endurance performance is decreased by 7% to 60% at a dehydration level of 2% to 7%. In temperate conditions, dehydration by 1% to 2% did not influence endurance performance when exercise duration was below 90 minutes. When, in the same environment, exercise duration was above 90 minutes and dehydration was 2% or greater, endurance performance was affected. This indicates that dehydration of 2% or greater reduces endurance performance in temperate and hot environments, when the duration of exercise is longer than 90 minutes. As the duration of a common surfing session can be up to several hours and surfing is often carried out in hot environments, these results are likely to be applicable to surfers. However, looking at the individual studies, it is noticeable that most studies use lower body aerobic exercise tasks such as exercise on a cycle ergometer, running, hiking or bench steps to measure endurance performance. This might be less applicable for surfing, as surfing demands particularly upper body aerobic endurance. Further, exercise which implies the resistance of the athlete's own body weight, for example running or performing bench steps has to be interpreted with caution. Such exercises might mask the effects of dehydration, because of the decrease in resistance with decreasing body weight (Judelson et al., 2007).

A recent meta-analysis by Savoie, Kenefick, Ely, Cheuvront & Goulet (2015) investigates the effect of hypohydration on both, upper and lower body aerobic endurance, separately, including only studies that were body weight independent. The analysis includes six studies on upper body muscular endurance and ten studies investigating lower body aerobic muscular endurance. It was found that upper body muscular endurance performance decreased significantly by 8.4 ± 3.3% at a mean hypohydration level between conditions of 2.6 ± 0.8% (95% CI: -14.9 to -2.0). Lower body muscular endurance decreased significantly by 8.2 ± 3.2% at a mean hypo-hydration level between conditions of 3.0 ± 0.7% (95% CI: -14.5 to -2.0). No significant difference (P=0.97) was found in outcomes between the upper and lower body limbs.

These studies show that dehydration of 2% to 3% or greater can impair upper and lower body aerobic performance significantly, especially when exercise duration exceeds 90 minutes or when exercise is performed in hot environments (>30°C) which is likely in surfing.

Upper and lower body muscular strength

Considering the activity profile of surfing, as discussed in the chapter before, upper body muscular strength might be especially important for sprint paddling to catch waves, ducking the surfboard under waves and standing up quickly on the board when a wave is caught. Further, lower body muscular strength is required when performing manoeuvres on the unbroken section of the wave and was found to be a good indicator for surfing performance (Tran et al., 2015). Therefore, the literature was searched for studies investigating the influence of dehydration on these factors in order to get insight into the effect of hydration on surfing performance.

Several studies could be found investigating the influence on dehydration on upper and lower body strength. Carrasco (2008) investigated general upper and lower body strength endurance in Australian surfers after as compared to before a 100-minutes surfing session under two different hydration conditions (with and without fluid ingestion during the training). Lower body strength endurance (LBE) was measured by means of a 1-minute step test, where participants performed as many step-ups as possible within one minute. Upper body strength endurance (UBE) was measured using a 1-minute push up test, where each participant had to complete as many push ups as possible within one minute. Carrasco (2008) found that in the no fluid ingestion trial, at a body mass loss of 3.9%, both UBE and LBE were reduced by 21.2 ± 5.5% and 4.4 ± 5.8%, respectively. In the fluid ingestion trial upper body strength endurance was reduced by 17.0 ± 4.1%, which was significantly lower than when no fluid was ingested (P=0.01). Further lower body endurance increased by 1 ± 3% in the fluid ingestion trial which was significantly higher than in the no fluid ingestion trial. Remarkably, there was a substantial decline in UBE in the fluid ingestion trial, whereas LBE even increased. A possible explanation can be found in the time motion analysis of surfing which shows that LBE which is specific to wave riding accounts for 2-5% of a surfing session, whereas UBE which is required for paddling accounts for about 44-51% of the time surfing (Meir et al., 1991; Mendez-Villanueva et al., 2006; Secomb et al., 2015). Therefore the higher declines in UBE compared to the decline in LBE might be due to the higher energy demands of the upper body during surfing which might impair post-training UBE. Further the results for LBE and UBE must be evaluated with caution, as both, the step-test and push-up test rely on body mass as resistance instead of a fixed weight. Therefore the tests were easier at the conclusion of the surfing session when the surfers had lost body mass. This might explain the increase in LBE in the fluid ingestion trial. The increase in LBE might thus be due to a decrease in resistance rather than an actual increase in LBE. Further, the effect of dehydration on muscular strength endurance might be greater than reported in this study.

Moreover, these findings are in line with the results of the meta-analysis by Savoie et al. (2015) which show that both, upper body muscle strength and lower body muscle strength were impaired by -3.7 ± 1.8% and -6.2 ± 1.1%, respectively, (95% CI: -7.2 to -0.2; 95% CI: -8.5 to -4.0) at a hypohydration level of 2.9 ± 1.0% and 2.7 ± 1.1%, respectively. Overall, the meta-analysis covers 85 individual studies of which 14 investigate upper body muscle strength and 25 investigate lower body muscle strength. For the assessment of the impact of hypohydration on lower and upper body strength Savoie et al. (2015) only included studies with testing procedures that were body weight-independent.

Another meta-analysis performed by Goulet et al. (2010) included 11 studies that investigate muscle strength. The study found that at a mean body weight loss of 3 ± 1.3% mean lower body strength declined by 5.8% (95% CI: 3.2 to 8.5%) and mean upper body strength declined by 4.8% (95% CI: 2.9 to 6.8%). Unfortunately, the study was only published in poster and abstract form. It is therefore not clear if the authors only included studies with testing procedures that are body weight independent or whether they also included studies that used body weight dependent testing procedures. Nevertheless, all of the abovementioned studies are in line and indicate that body weight losses of more than 2.7% may impair lower and upper body muscular strength significantly. In surfers, this might have an impact on their sprint paddling performance, ability to duck their board under waves and their ability to perform manoeuvres when riding a wave.

Jumping ability

Besides lower body muscular strength, jumping ability is expected to be an important physical characteristic for performing manoeuvres on the unbroken section of the wave and thus a good indicator for surfing performance (Tran et al., 2015).

The meta-analysis performed by Goulet et al. (2010) includes four studies assessing jumping ability and shows that hypohydration with a mean body weight loss of -2.5 ±1.2% across the different experimental groups resulted in a non-significant decrease in mean jumping ability of 0.34 ± 3.60% (95% CI: 2.10 to 1.42%) compared with the control group.

Similar, the more recent meta-analysis by Savoie et al. (2015), which includes 12 studies on jumping ability, found that vertical jumping ability increased not significantly (P=0.16) by 0.9 ± 0.7% compared with the well-hydrated condition. The difference in hypohydration level between the hydration conditions was 2.7 ± 1.1%

It is not surprising that jumping ability does not decrease significantly with hypohydration, as resistance decreases with decreasing body weight. For this reason hypohydration is in fact expected to increase jumping ability (Cheuvront et al., 2010). Therefore, Cheuvront et al. (2010) examined the effect of hypohydration on vertical jump performance using a weighted vest to compensate for the weight loss in the hypohydration trial in order to assess why hypohydration does not improve jump height. Fifteen healthy and active males performed the counter-movement jump test in a cross-over design under three different conditions: euhydrated (EUH), 3.8% hypohydrated (HYP) and hypohydrated while wearing a weighted vest adjusted to match water mass losses (HYPv). The results show that vertical ground reaction impulse was reduced by 2 to 3% in both hypohydration conditions compared with EUH (P<0.05). Further, there was no difference in jump height between EUH and HYP, but jump height was 4% lower (P<0.05) in HYPv than EUH. Also, jump velocity was significantly lower in the HYPv trial compared to the HYP and EUH trial (P<0.05). These findings indicate that jumping performance is likely to be impaired by a hypohydration level of 3.8% and that this impairment can be masked by changes in the strength-to-mass ratio. Considering the activity profile of surfing, jumping ability might play an important role for surfing performance when performing manoeuvres on the unbroken section of the wave. When performing manoeuvres, such as bottom turns, a series of compression and extension movements of the legs are performed, similar to jumping (Tran et al., 2015; Young, 1988). However, it is not yet clear what the critical dehydration level is, above which jumping ability is affected. Therefore, further research is needed to examine jumping ability at different grades of dehydration while controlling for weight loss.

Cognitive function

During the whole process of surfing – starting with the observation of the wave conditions on the beach – excellent cognitive function is required in order to identify changes in wave conditions and currents and respond accordingly. Therefore, the existent literature was searched to investigate the possible influence of hydration on cognitive function.

Recent reviews indicate that dehydration that reduces body mass by more than 2% impairs cognitive performance (Benton & Young, 2015; Adan, 2012; Lieberman, 2007) and that water consumption can have a positive effect on cognitive function (Masento, Golightly, Field, Butler & van Reekum, 2014). Studies investigating the influence of dehydration on cognitive function often use different cognitive tests in combination with different dehydration methods.

Also, part of them fails to control for confounding factors (Lieberman, 2012). Therefore, it is difficult to summarize the results and it is necessary to analyse the individual studies.

A commonly cited article is the study of Gopinathan, Pichan and Sharma (1988) which investigates the variation of mental performance under different levels of dehydration in 11 healthy and heat acclimatized subjects. The subjects were dehydrated by a combination of fluid restriction and exercise in the heat to the degree of 1%, 2%, 3% and 4% of their body mass on separate testing days. After recovery from the effects of exercise in heat different mental domains were assessed (arithmetic ability, short-term memory, and motor speed and attention). Before the start of the actual experiment, several practice trials were completed in order to prevent learning effects that would confound the results. It was found that at a dehydration level of 2% impairment of all mental functions becomes highly significant ($P<0.001$) and that deterioration of all mental functions is proportional to the degree of dehydration. It is not clear if the effects might also be due to heat exposure, although participants were allowed to recover from the heat stress. It can be concluded that dehydration induced by exercise in the heat in combination with fluid restriction leads to significant changes in arithmetic ability, short-term memory, motor speed and attention. As surfing is often carried out in warm environments these results are likely to be applicable to surfing. Although no conclusions can be drawn from this study on the effect of impaired mental functions on surfing performance, it is expected that mental performance plays an important role as surfers need to identify and respond to environmental cues such as wave conditions and currents in order to identify superior waves and stay safe on the water (Young, 1988). As discussed in the previous chapter, Carrasco (2008) found that short-term memory, working memory, information processing, attention, visuomotor skills and visual acuity were associated with surfing performance scores. Keeping in mind that association does not imply causation, these results are in line with the expectation that mental performance is linked to surfing performance and hence, the results of Gopinathan et al. (1988) are likely to be applicable to surfers. In order to see if the abovementioned results are indeed crucial to surfers the level of dehydration surfers develop during a common surfing session needs to be investigated.

The abovementioned study by Carrasco (2008) also investigated cognitive function before compared to after a 100-minutes surfing session and under two different hydration conditions. When the participants did not ingest any fluids (3.9% body mass loss) during the surfing session all domains of cognitive function were impaired, whereas cognitive function was maintained or even improved in the fluid ingestion trial (1.6% body mass loss). In all cognitive domains a strong relationship with hydration status (range: $r=0.80 – 0.89$; $P<0.05$) could be found. These results indicate that sweat loss during a 100-minutes surfing session without fluid ingestion is sufficient to impair mental performance. Hence, exercise induced dehydration during surfing of more than 2% is likely to impair several domains of cognitive function that might be linked to surfing performance. This highlights the importance of research on hydration in surfers.

The study of D’Anci, Vibhakar, Kanter, Mahoney &Taylor (2009) assessed several cognitive domains (including vigilance attention, short-term memory, simple and choice reaction time, map planning, visual perception and mathematical addition) in 31 male and female athletes participating in men’s and women’s crew rowing and women’s lacrosse. The participants completed a normal training session of 60 minutes (crew rowing team) or 75 minutes (lacrosse team) and were randomly assigned the euhydrated or dehydrated trial in a cross-over design. Euhydration or dehydration was achieved by completing the training session with or without water replacement which resulted in a mean body mass loss of 1.82% in the dehydrated trial and 0.05% in the euhydrated trial. No significant effect of hydration condition was found for short-term memory, simple and choice reaction time, map planning, mathematical addition and visual perception. However, during the continuous performance task of 15 minutes reaction time increased ($P<0.01$) over time in the dehydrated trial, showing a decrease in vigilance, whereas reaction time in the euhydrated trial stayed stable.

These results are in line with the results of Gopinathan et al. (1988) which show that effects on cognitive function become significant at a dehydration level of 2%. As the mean body mass loss in this study was below 2% this might explain that no effect was found in the simple mental performance tasks. However, cognitive performance was affected significantly on the more demanding continuous performance task which shows that dehydration levels below 2% might affect cognitive performance in more complex situations whereas simple cognitive tasks are not impaired. As surfing is expected to require several different domains of cognitive function, performance might even be impaired by dehydration levels below 2%.

Surfing performance
From the abovementioned studies it can be concluded that dehydration affects upper body aerobic performance, upper and lower body muscle strength, jumping ability and cognitive function. Although these factors are expected to influence surfing performance, it is not clear to what extent actual surfing performance is affected by dehydration.

Only one study could be found investigating the effect of dehydration on actual surfing performance. The study by Carrasco (2008) included 12 Australian national and international-level surfers and compared actual surfing performance during a 100-minutes surfing session in surfers who did not ingest any fluid during the session (no fluid ingestion trial) and surfers who consumed 3 ml/kg body mass of water every 20 minutes during the surfing session (fluid ingestion trial) in a cross-over design. All surfers started the study sufficiently hydrated (U_{sg} <1.015 g/ml). The mean body mass loss in the no fluid and fluid ingestion trial was 3.9 ± 0.7% and 1.6 ± 0.7%, respectively. Surfing performance was assessed in all surfers during the first and last 20 minutes of the 100-minutes training session by the same three experienced judges. In the no fluid trial the surfing performance score of the first 20 minutes compared to the last 20 minutes of the session decreased by 20.3 ± 7.1%. This was significantly greater ($P<0.05$) than in the fluid ingestion trial where even a slight improvement in surfing performance of 1.9 ± 10.2% could be seen. Also, a correlation between dehydration and surfing performance was found ($r=0.75$; $P < 0.05$). However, the study has some limitations. The main limitation concerns the small number of subjects (n=12). Thus potential bias of individual scoring or changing surf conditions cannot be excluded. Overall, this study supports the previous findings in this chapter and highlights the importance of hydration in surfing. In order to draw conclusions on hydration in surfers, the body mass loss during a common surfing session, as well as typical hydration behaviour of surfers needs to be further investigated.

3.2. Fluid Intake of Surfers

The results of the previous chapter emphasize the importance of hydration for surfing performance. Therefore, in this chapter a literature search was conducted for studies assessing the actual amount of fluid intake of surfers. Only two studies have been found that investigate the fluid intake of surfers. Felder et al. (1998) assessed the dietary practices of ten elite female surfers during competition and training, whereas the more recent study of Costa (2012) assessed the nutritional and fluid intake of thirteen professional and non-professional male surfers during a national championship. Both studies used food diaries in order to investigate the food and fluid intake. The diaries in the study by Felder et al. (1998) were completed over a period of four consecutive days during competition and during five consecutive days during training and revealed a fluid intake between 443 and 998 gram of fluid on training days and between 399 and 2660 gram on competition days. The participants of the study of Costa (2012) only completed one-day-diaries. The results show that mean water intake from fluids and food amounted to 1367 ± 496 millilitres per day with a minimum intake of 478 millilitres and a maximum intake of 2056 millilitres.

Beforehand participants of both studies were instructed on how to record their intakes accurately and the participants were informed about the importance of registering all foods and fluids ingested during that day. However, self-report-methodology is susceptible to several limitations. Although self-reported fluid consumption was found to have a strong linear relation with direct measurement in triathlon athletes (Wilson, Rhodes & Ingraham, 2015), it is susceptible to over- and underestimation (due to difficulties in estimating serving sizes, alterations of the usual intake during the period of monitoring or inaccurate reporting). Such data therefore needs to be interpreted with some caution (Magkos & Yannakoulia, 2003; Wilson et al., 2015). Particularly sports drinks are likely to be under-reported as they are generally consumed between meals (Magkos & Yannakoulia, 2003).

Keeping in mind these limitations, the results of both studies might not represent an accurate measurement of the actual amount of fluids ingested. Both studies show a relatively large variability in between minimum and maximum registered fluid intakes. In the study by Costa (2012) only one-day diaries were used which might not be representative for the usual food and fluid intake of the participants because of the possibly large intra-individual variability between days (Wilson et al., 2015). Further, the results of Costa (2012) show a large inter-individual with a minimum intake of 478 millilitres and a maximum intake of 2056 millilitres. The large variability might make it difficult to draw general conclusions on the mean fluid intake of surfers, but indicates that drinking behaviour is highly variable between persons and therefore highlights the importance of individual advice concerning optimal hydration. The results of the study of Felder et al. (1998) might give a better indication of the usual intake of the individual participants due to the longer recording period, but still there might be large inter-individual differences as presented in the study of Costa (2012), which makes it difficult to generalize results.

Lastly, none of the abovementioned studies recorded sweat rate, duration of training or competition, wetsuit type and environmental conditions. All of them might, however, be important factors when interpreting fluid intake, because of their possible influence on fluid loss. A common surf practice can be several hours in duration (Felder et al., 1998; Meir et al., 1991; Mendez-Villanueva et al., 2006) and during competition multiple sessions of 20 to 40 minutes duration might be completed (Felder et al., 1998; Mendez-Villanueva et al., 2006). Further, Carrasco (2008) observed a sweat loss of 2.8 ± 0.6 kilograms in Australian surfers during a 100-minutes surfing session in a steamer wetsuit. Taking into consideration the sweat rate and duration of a common surfing session it is expected that even the maximum reported fluid intake of the surfers in the studies of Felder et al. (1998) and Costa (2012) might not compensate for sweat losses which might lead to dehydration. Though, it has to be kept in mind that under-reporting of fluid intake might have occurred, as discussed above, and that data on fluid ingestion might not be representative for all surfers, as large intra- and inter-individual differences in food and fluid ingestion have been observed.

The scarcity of research examining the hydration behaviour of surfers and the methodological limitations of the existing studies clearly shows the necessity of further research in this area. Future research is needed to investigate the hydration behaviour of surfers preferably by means of direct measurement of the fluid intake and/or by means of objective parameters such as urine or blood parameters measuring the hydration status. Further it is important to record factors such as climate, type of wetsuit and duration of the competition or training session as those factors are hypothesized to influence sweat rate. Finally, future studies should aim for a large sample in order to compensate for variability.

4. RESULTS FIELD STUDY

Overall, 25 male surfers volunteered to participate in the study. Because of an error in measurement in one case and limited time (< 30 minutes) spent on the water in two cases, only data of 22 participants is included in the analysis. An overview of the individual results of the participants can be found in Appendix 4.

4.1. Characteristics of the Participants

The participants' mean age, height, body mass and surfing experience was 30.0 ± 6.1 years, 177.6 ± 7.9 centimetres, 74.2 ± 9.6 kilograms, 6.8 ± 5.1 years, respectively. All of the participants were recreational surfers who did not take part in any competitions. Fifty-nine per cent (n=13) of the participants indicated that they usually surfed as often as several times per week, 23% (n=5) usually surfed once a week, 5% (n=1) surfed several times per month, 9% (n=2) surfed once per month and 5% (n=1) usually surf less than once a month. The mean time that the participants reported to usually spend on the water is 122.7 ± 63.4 minutes ranging from 60 to 360 minutes.

4.2. Environmental Factors

The data was collected at the following surf spots in Southeast Queensland and the northern part of New South Wales: Burleigh Heads, Coolum Beach, Greenmount, Kirra Beach, South Stradbroke Island, Tallow Beach, The Pass, Wurtulla Beach.

The weather conditions varied between the testing days. The mean water and air temperature on the testing days was 25.9 ± 0.3 °C and 23.7 ± 1.2 °C, respectively. The wave conditions were highly variable between the testing days. The swell size was in between 1-2 and 6 foot.

Twenty of the 22 included participants wore only board shorts or board shorts in combination with a lycra, T-Shirt or wetsuit top. The remaining two participants wore a short wetsuit and a full length wetsuit, respectively.

The time that the participants spent on the water during the testing days correlated with the indicated time they usually spend on the water ($r=0.87$; $P<0.001$). However, the average duration of the surfing session during the testing days was 23.7% shorter than the indicated usual duration of a surfing session.

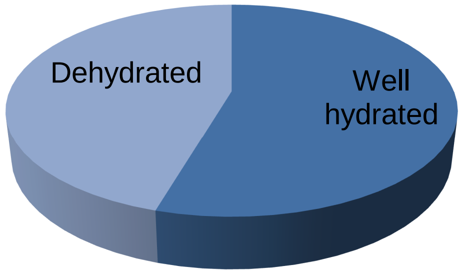
4.3. Hydration Status Prior to Surfing

Using the common cut-off value of 1.020 g/ml (Casa et al., 2000; Armstrong et al., 2010; Opplinger & Bartok, 2002), in the present study 55% (n=12) of the participants started their surfing session well hydrated (U_{sg} ≤1.020 g/ml) and 45% (n=10) of the participants were dehydrated (U_{sg} > 1.020 g/ml) at the start of their surfing session (see Figure 2).

The average U_{sg} of all samples was 1.019 ± 0.007 g/ml, ranging from 1.007 to 1.038 g/ml.

Figure 2 Percentage of surfers well hydrated and dehydrated prior to the surfing session

	N	%
Well hydrated	12	55%
Dehydrated	10	45%



4.4. Body Mass Measurements

The mean sweat rate of all participants was -0.48 ± 0.36 litres per hour. The mean percentage of body mass loss was -0.6 ± 0.5% per hour. Further, the difference in mean body mass before surfing, compared to after surfing was significant (P<0.001).

4.5. Hydration Behaviour

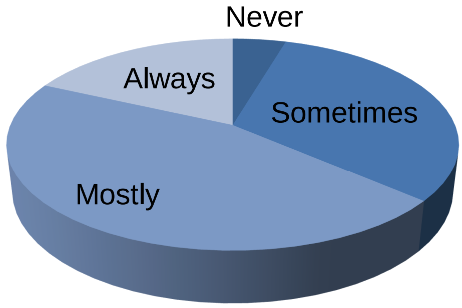
When asked about their hydration behaviour prior to surfing 37% (n=8) of the participants indicated that they drink extra fluids only "sometimes" or "never" before surfing. Eighteen percent (n=4) of the surfers indicated that they always ingest extra fluid before surfing and 45% (n=10) "mostly" ingest extra fluid. In contrast, 77% (n=17) indicated that they "always" or "mostly" drank additional fluids after surfing and 23% (n=5) "sometimes" consumed extra fluid (see Figure 3).

No significant difference could be found between mean U_{sg} of participants who "always" or "mostly" ingest fluid before surfing and participants who "never" or "sometimes" ingest fluid before surfing (P>0.05). Also, the difference in mean U_{sg} of participants who "always" or "mostly" ingest fluid after surfing and participants who "never" or "sometimes" ingest fluid after surfing was not significant (P>0.05). Further, no significant difference could be found in mean sweat rate of participants who "always" or "mostly" ingest fluid after surfing and participants who "never" or "sometimes" ingest fluid after surfing (P>0.05).

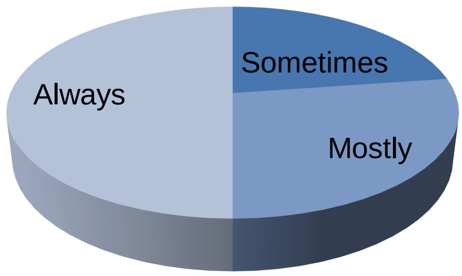
When asked to rate the importance of hydration for surfing performance on a scale from one (not important) to ten (very important), the participants gave a mean score of 8.1 ± 1.7. The given scores ranged from 4 to 10. A weak negative, but not significant correlation could be found between U_{sg} and hydration-importance-rating (r=-0.103; P>0.05).

Figure 3 Self-reported fluid ingestion before and after surfing in the present study

Fluid ingestion before surfing	N	%
Never	1	5%
Some-times	7	32%
Mostly	10	45%
Always	4	18%



Fluid ingestion after surfing	N	%
Never	0	0%
Some-times	5	23%
Mostly	6	27%
Always	11	50%



5. DISCUSSION AND CONCLUSION

The aim of this study was to get insight into hydration in surfers and the possible implications on surfing performance. To date, limited research has been conducted on hydration in surfers and, to our knowledge, no study ever measured the hydration status of surfers before a surfing session.

Although the participants rated hydration important for surfing performance, almost half of the participants started their surfing session dehydrated as indicated by a U_{sg} greater than 1.020 g/ml. Also, no significant correlation could be found between rating of importance of hydration for performance and hydration status before surfing. Provided the U_{sg} measured on the testing day is representative for the participants' usual hydration status before surfing, this indicates that although the participants think that hydration is important for surfing performance, a great part of them fails to be sufficiently hydrated at the start of their surfing session.

The present study aimed to get insight into the hydration behaviour of surfers by searching the literature for studies investigating the actual amount of fluid intake of surfers and by asking the participants about their usual drinking behaviour before and after surfing. Studies that investigated the actual amount of fluid intake of surfers are difficult to interpret due to the methodological limitation of self-reported fluid intake (as discussed in chapter 3.2.). Further, these studies did not investigate sweat loss during surfing and therefore no conclusions can be drawn over the adequacy of fluid intake from these studies. However, these studies show that there is a high inter-personal variability concerning fluid intake. This might be an important result which highlights the importance of individual guidance.

According to the questionnaire in the present study more than one third of the participants "never" or only "sometimes" ingested extra fluid before surfing and only 18% reported that they "always" ingest extra fluid before surfing. In contrast, more than three quarter of the participants "mostly" or "always" drank additional fluids after surfing. The results of this study are in line with the results of the study of Meir et al. (2011). In both studies the percentage of surfers who indicate to "always" or "mostly" drink extra fluids after surfing is higher than the percentage of surfers "always" or "mostly" ingesting extra fluid before surfing (see Table 1). A possible explanation for the difference in hydration behaviour after compared to before surfing, as well as the discrepancy in the rating of importance of hydration and the actual hydration status before surfing, is the sensitivity of the thirst mechanism. The sensation of thirst typically lags behind the fluid deficit, and dehydration may reach 1 to 2% of body mass before the thirst mechanism is stimulated (Benelam & Wyness, 2010). Therefore the surfers might not feel thirsty yet before the surfing session and therefore drink less frequently before surfing than after surfing, when fluid deficits stimulate the thirst mechanism. Supported by the fact that almost half of the surfers started their surfing session in a dehydrated state, this indicates that a great part of the surfers fails to be adequately hydrated before the start of a surfing session and may risk significant dehydration depending on the duration of their sessions and their sweat rate.

Table 1 Hydration behaviour of the participants in the present study compared to the study of Meir et al. (2011)

	Present study				Meir et al. (2011)			
	fluid ingestion before		fluid ingestion after		fluid ingestion before		fluid ingestion after	
	N	%	N	%	N	%	N	%
Never	1	5%	0	0%	153	24.8%	195	31.6%
Sometimes	7	32%	5	23%	-	-		
Mostly	10	45%	6	27%	-	-	422	68.4%
Always	4	18%	11	50%	132	21.4%		

The mean sweat rate of the participants in the present study was -0.48 ± 0.36 litres per hour. This is comparable to the sweat rate reported by recent studies in swimmers and water polo players, but lower than the sweat rate measured in athletes performing land-based sports (see Table 2). Henkin, Sehl and Meyer (2010) investigated the difference in sweating responses between swimmers and land-trained individuals by comparing the sweat rates of swimmers, runners and non-athletes during a 30-minutes cycling test. They found that the sweat volume, in litres per hour, of swimmers (0.9 ± 0.3) was significantly lower ($P < .05$) than that of runners (1.5 ± 0.2) and similar to that of non-athletes (0.6 ± 0.2). This indicates that sweat responses are dependent on the training environment (on land or in water). The aquatic environment may facilitate body heat transfer through conduction and convection, limiting sweating. Therefore, sweating in water-based sports such as surfing might play a less crucial role than in land-based sports. In contrast to these findings, the surfers in the study of Carrasco (2008) lost 2.9 ± 0.6 litres during a 100-minutes surfing session, which equates to a mean sweat rate of 1.68 litres per hour. This is considerably higher than the sweat rate of the surfers in the present study and the reported sweat rate of swimmers and water polo players. A possible explanation for the differences in sweat rate is the insulating properties of a wetsuit. In the present study most participants wore board shorts in contrast to the study of Carrasco (2008) where all participants wore a 2x3 millimetres sealed and seamed full length wetsuit. The insulating properties of a wetsuit are a possible explanation for the difference in sweat rates between the two studies. Neoprene wetsuits reduce convective heat loss during water immersion by trapping a layer of water between the wetsuit and the skin which is warmed up by the body and creates a barrier between the skin and the cold water surrounding the body (Naebe, Robins, Wang & Collins, 2013). Therefore, individuals wearing board shorts during surfing are expected to have a lower sweat rate due to increased heat loss by convection compared to individuals wearing a wetsuit. Another important observation is the wide range of data obtained on sweat rate in all of the studies (see Table 2). This indicates that there is a need for individual guidance concerning optimal fluid replacement after exercise.

The sweat loss in the present study resulted in an average change in body mass of 0.6% during one hour of surfing. A dehydration level of 2-3% affects cognitive function, upper body aerobic performance, upper and lower body muscular strength and is thus likely to impair surfing performance. Four of the 22 participants in the present study lost at least one per cent of their body mass during one hour of surfing. As the average time that the participants generally indicated to stay on the water was about two hours and some even indicated to stay on the water for up to four hours, those surfers may produce a significant level of dehydration to impair surfing performance. In combination with hypohydration before the start of the surfing session, even a greater part of the participants may produce a significant level of dehydration for performance to be impaired. According to Casa et al. (2000) a U_{sg} between

1.021 and 1.030 may reflect 3% to 5% hypohydration. In the present study almost half of the participants had a U_{sg} greater than 1.020. Consequently, although the fluid loss during one hour of surfing averaged only 0.6%, the level of dehydration at the end of the surfing session, in combination with pre-exercise hypohydration or a longer duration of the surfing session a great part of the participants may reach a significant level of dehydration and impairment of surfing performance. Considering the mild conditions of most of the testing days, longer and possibly more demanding surf sessions, the use of a wetsuit and increased water and air temperature might further increase fluid losses (Sawka et al., 2007). In order to prevent the effects of dehydration on surfing performance, surfers need to be educated about the importance of hydration prior to a surfing session.

Moreover, a few statistical tests were performed to investigate whether there is a link between the hydration behaviour of the participants and their hydration status and hydration behaviour and sweat rate.

It was expected that surfers who indicated that they “always” or “mostly” ingest extra fluid before a surfing session would have a lower U_{sg} and therefore be better hydrated than those who indicated to ingest extra fluid only “sometimes” or “never”. However, no significant difference could be found in between the two groups. This might indicate that even if the participants ingest extra fluid before their surfing session it might not be sufficient to result in a good hydration status before the start of their surfing session.

Also, it was hypothesized that surfers who indicated that they “always” or “mostly” ingest extra fluid after a surfing session might do so because of a higher U_{sg} before surfing, compared to those who only “sometimes” or “never” ingest extra fluid after surfing. However, no difference was found in mean U_{sg} in between the two groups. This is in line with the findings by Osterberg, Horswill and Baker (2009) who found that the volume of voluntary fluid intake of professional basketball players was not correlated with pregame hydration status as assessed by means of U_{sg}. In contrast to that, Maughan, Shirreffs, Merson and Horswill (2005) noted a significant relationship between pre-training hydration status, as assessed by urine osmolality, and volume of fluid intake during training in professional soccer players. The cause of the discrepancy between the different studies is unknown. However, fluid ingestion following exercise is probably dependent on more factors than hydration status before the exercise session alone, which may explain the discrepancy in results. Another factor might be the amount of sweat lost during exercise, which is influenced by factors such as duration and intensity of the exercise task, environmental factors and clothing (Sawka et al., 2007).

Lastly, it was expected that participants who “always” or “mostly” ingest extra fluid after a surfing session might do so because of a higher sweat rate compared to those participants who only “sometimes” or “never” ingest extra fluid after surfing. Though, no significant difference could be found in sweat rate between the two groups. Thus, surfers with a higher sweat rate do not differ in hydration behaviour to surfers with a lower sweat rate. These findings are similar to the study by Maughan et al. (2005) that found no significant relationship between the volume of fluid consumed during training and the amount of sweat loss in professional soccer players. The missing correlation may be due to other possible factors influencing fluid intake, such as hydration status before surfing and the actual amount of fluid lost depending on the duration of the surfing session.

Nevertheless, correlations between the reported hydration behaviour and the measured U_{sg} and sweat rate on the testing day need to be interpreted with caution. The correlations were made under the assumption that the measured U_{sg} and sweat rate are representative for all surfing sessions and that the hydration behaviour reported by the participants reflects their hydration behaviour on the testing day.

Several conclusions can be drawn from this study:

1) There is a clear discrepancy between the knowledge about the importance of sufficient hydration for surfing performance and the information given on usual fluid intake before and after surfing. The discrepancy is confirmed by U_{sg} measurements before the surfing sessions. As indicated by U_{sg} measurements almost half of the surfers started their surfing session in a dehydrated state. When giving advice to surfers about optimal hydration, the importance of hydration before surfing should be stressed.

2) The mean sweat rate is comparable to the sweat rate observed in athletes of other water-based sports, but lower than the sweat rate observed in land-based sports. Sweat losses during surfing resulted in an average body mass loss of 0.6% per hour. Coupled with hypohydration before the start of the surfing session or a longer duration of the surfing session a great part of the participants may reach a significant level of dehydration to impair surfing performance. Considering the mild conditions of most of the testing days, longer and possibly more demanding surf sessions, the use of a wetsuit and increased water and air temperature might further increase fluid losses and therefore increase dehydration levels and impairment of performance.

3) Similar to studies in other disciplines a wide range of data was obtained on sweat loss, which highlights the need for individualized fluid-replacement guidance.

4) The results highlight, that fluid replacement guidance should be individualized and based on the individual sweat rate of the surfer (under different environmental conditions and considering the type of wetsuit). Further, when giving advice to surfers, the importance of hydration before surfing should be stressed.

Based on the main findings of this study a fact sheet is created for dietitians and surf coaches with practical recommendations for optimal hydration in surfers which can be found in Appendix 5. This fact sheet will help dietitians and surf coaches in giving advice to surfers concerning hydration.

Table 2 Sweat rate observed in different water-based and land-based sports

Source	Athletes (N, gender)	Environmental conditions	Mean sweat rate
		Water-based sports	
Carrasco, 2008	Australian surfers (12, male)	Mean water temperature: 20.8 ± 1.4 °C	1.68 L/h
Cox, Broad, Riley & Burke, 2002	Water polo players (23, male)	Water temperature during training: 27.2 (27.0-27.5) Water temperature during competition: 27.3 (27.2-27.4) Air temperature during training: 23.9 (23.1-24.6) Air temperature during competition: 24.1 (23.7-24.4)	During training: 0.287 L/h (range: 0.228-0.346 L/h) During competition: 0.786 L/h (range: 694-878 L/h)
Maughan, Dargavel, Hares & Shirreffs, 2009	Nationally ranked swimmers (9, male; 8, female)	Mean water temperature: 27.4 °C; mean air temperature: 36 °C.	0.31 L/h (range: 0.07–0.57 L/h)
Soler, Echegaray & Rivera, 2003	Competitive swimmers (9, male)	Mean water temperature: 26.8 ± 0.3 °C; mean wet bulb globe temperature: 29.8 ± 2.8 °C	0.5 L/h
Present study	Recreational surfers (22, male)	Mean water temperature: 25.9 ± 0.3 Mean air temperature: 23.7 ± 1.2	0.48 L/h (range: 0.07-1.35 L/h)
		Land based sports	
Godek, Bartolozzi & Godek, 2005	American football players (10); runners (5)	Mean on-field temperature morning practice: 28.4˚C, mean on-field temperature afternoon practice: 34.5˚C	American football players, morning: 2.15 L/h American football players, afternoon: 2.12 L/h Runners, morning: 1.56 L/h Runners, afternoon: 1.97 L/h
Lott & Galloway, 2011	Tennis players (16, male)	Mean air temperature: 17 ± 2 °C	1.1 L/hr (range: 0.3–2.0 L/hr)

6. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Sample size: This study aimed to include 30 participants. Because of the limited time and the wave conditions only 22 participants could be included. During the months November and December, when data collection took part, the wave conditions are often inconsistent on the Australian East coast. The prevailing north-easterly winds during summer bring a north-east swell that is usually choppy with waves close together (Young, 1988). Because of the wave conditions it was difficult to choose the testing days and the time that participants spent in the water was mostly shorter than usual. For future research it is recommended to collect data during cyclone season (December to March) when wave conditions are more consistent (Young, 1988). A greater sample would enhance the reliability of the results.

Generalisability of the results: Firstly, females were excluded in this study, because of the influence of the menstrual cycle and the use of contraceptives on water retention and kidney function (Benton & Young, 2015) which makes it difficult to measure the hydration status in the female population. Therefore only conclusions for the male surfing population can be made and recommendations are only applicable for male surfers. However, in the context of hydration, there is a need to compare males and females, and there is a need to consider the stage of the menstrual cycle and the use of oral contraceptives.

Second, only participants from the south-eastern part of Queensland and the northern region of New South Wales were included. Because the participants were tested on several different beaches and on different testing days, the sample is expected to be representative for surfers of this region and might also be representative for surfers of other regions presenting a similar subtropical climate and water temperature. Different water temperatures have an influence on sweat rate. Macaluso et al. (2005) measured the sweat rate and degree of dehydration in nine male competitive swimmers during a 5-kilometer race in three different water temperatures (23, 27 and 32 °C) in a cross-over design. They found that percentage of dehydration and sweat rate were the highest at 32°C and the lowest at 23°C. The results of this study show that dehydration and sweat rate simultaneously increase with the rise of water temperature in swimmers during a 5-kilometer race. This suggests that dehydration and sweat rate in surfers might be increased when surfing in water of a higher temperature, similar to swimmers. The mean water temperature in this study was 25.9 °C. As the water temperature influences sweat rate the results of this study are only valid for individuals surfing under the same environmental conditions. Further research on sweat rate in a greater sample of surfers and under different environmental conditions is recommended.

All but two of the surfers in this study surfed in board shorts only or board shorts in combination with a wetsuit top, lycra or T-shirt. It is expected that wearing a wetsuit during surfing increases the sweat rate. Therefore, the results are only applicable to surfers surfing in board shorts. Further research is needed to investigate the influence of wearing a wetsuit during surfing on the sweat rate.

All of the surfers in this study were recreational surfers. Further research is needed to investigate weather professional surfers differ from recreational surfers concerning their hydration behaviour and sweat rate. Sweat rate in professional surfers might be different to the sweat rate in recreational surfers due to a possible difference in exercise intensity (Sawka et al., 2007).

Errors in measurement were reduced to a minimum by calibrating the refractometer at the start of each testing day and weighing all participants on the same scale and under the same conditions before and after surfing (wetted hair and board shorts, weighing in the same place). Though, measurement errors might have occurred due to field nature of the study.

Although the same scale was used in the same place before and after surfing, a slightly uneven underground might influence the accuracy of the scale. Further sources of errors might be the failure to account for water accidentally swallowed during surfing, failure to control for water absorbed by the skin, failure to compensate for respiratory and metabolic losses or urine losses during surfing.

Lastly, because of the limitations of self-reported fluid intake the fluid intake (as discussed in chapter 3.2.) the surfers' fluid intake was not measured directly on the testing day. Instead, the surfers were asked questions about their usual hydration behaviour. Therefore correlations between the reported hydration behaviour and the measured U_{sg} on the testing day need to be interpreted with caution. The usual hydration behaviour might not reflect the hydration behaviour on the testing day and U_{sg} might not be representative for all surfing days. For future research it is recommended to measure U_{sg} in a greater sample of surfers at least on two different surfing days which will allow better insight into the usual hydration behaviour of surfers. Correlations with drinking behaviour should be made with the actual amount of fluid that the surfers ingest on that day.

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APPENDIX 1: PARTICIPANT INFORMATION SHEET

PROJECT TITLE
"Hydration in male surfers during training in a subtropical environment "

INVESTIGATOR
Petra Koebrunner (B.Sc. student Nutrition and Dietetics, The Hague University of Applied Sciences)

SUPERVISOR
Dr Michael Leveritt (PhD, School of Human Movements, University of Queensland)

INVITATION TO PARTICIPATE IN STUDY
For my research on "Hydration in male surfers in a subtropical environment" at the University of Queensland I am looking for surfers willing to participate in my study. If you are a male surfer, aged between 18 and 50 years and not taking any medication that alters fluid balance (e.g. diuretic medication), I would like to invite you to take part in my study. If you are interested in being involved or wish to receive further information on the study please contact me. Participation in this research is completely voluntary and you may withdraw at any stage without having to provide a reason.

WHY IS THIS STUDY BEING CONDUCTED?
Research shows that dehydration in surfers can have adverse effects on surfing performance, cognitive function and muscular endurance. If cognitive function and muscular endurance are impaired this might have an impact on surf security and therefore optimal hydration should be a necessary part of surf practice.
This study aims to investigate hydration status prior to surf practice, sweat loss during a common surfing session and current hydration behaviour of surfers in South East Queensland, as well as the relation between hydration behaviour and sweat loss and the relation between hydration behaviour and hydration status prior to exercise.

WHAT ARE THE BENEFITS?
The results of this study will allow sports scientists, dietitians and coaches to get insight in the hydration practices of surfers. Further these insights will allow to form recommendations to optimize fluid intake in surfers which will support dietitians and coaches in giving practical advice concerning optimal hydration in surfers.

WHAT DO I NEED TO DO?
After you arrive on the beach on the test day you will be asked to provide a small urine sample (in order to measure your hydration status before the training) and have your body mass measured. Thereafter you will complete a surfing session as you normally do. When you come out of the water you will be asked to towel dry and change and your body mass will be measured again.
Additionally you will be asked to complete a short questionnaire about your characteristics as a surfer (e.g. data on age and height, surfing experience, usual time spent in the water per surfing session) and your drinking habits.

What are the discomforts and risks?

In order to avoid discomfort all urine testing and weighing will be performed out of the site of the public. Further there are no foreseeable risks or discomfort to you during this study beyond that of the normal risks when surfing. You need to know that the surfing session by itself is not part of the study and the procedures of the study are independent from the surfing session. Therefore surfing will be on your own risk. However, as a participant you are free to end the surfing session at any point for any reason without adverse consequences (e.g. if you don't feel comfortable with the wave conditions). Moreover, surfing sessions will be held at patrolled beaches in order to limit the possible risks during surfing to a minimum and ensure emergency treatment.

How will my privacy be protected?

The data collected will be used as part of a Bachelors thesis and for publications arising from this study. However, your personal data will be treated in confidence and will be used only for the purpose of this study. Only the main investigator and supervisor will have access to the data collected and neither name nor initials will be used to describe the data in any publications. Further the data will be stored using a coded number which can identify your data. Only the main investigator will have access to the codes and identity of the participants of this study. Should you wish to withdraw during the study your results will remain confidential and can be removed upon specific request.

What are my rights?

As a participant you are free to withdraw from the study at any time without adverse consequences.

Will I receive feedback on the results of this research?

If you wish so I will provide you with a copy of your personal results after the test day is completed. You may also ask for a summary of the overall results of the study.

How do I agree to participate in this study?

In order to participate in this research you will need to accept and sign the Consent Form, which I will provide you. You may contact me for any further questions concerning this study and signing the Consent Form.

Whom do I contact for further information about the study?

Any questions about this study are welcome. Please do not hesitate to contact the principal investigator, Petra Koebrunner, via email at petrakoeb@aol.com or by phone on +61 490250930.

Whom do I contact if I have a complaint about this research?

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the *National Statement on Ethical Conduct in Human Research*. Whilst you are free to discuss your participation in this study with project staff (contactable on contact number +61 490250930 or Email petrakoeb@aol.com). If you would like to speak to an officer of the University not involved in the study, you may contact Prof. Guy Wallis, the School of Human Movement and Nutrition Sciences Ethics Officer, on 3365 6180.

APPENDIX 2: INFORMED CONSENT SHEET

PROJECT TITLE: Hydration in male surfers during training in a subtropical environment

INVESTIGATOR: Petra Koebrunner (B.Sc. student Nutrition and Dietetics, The Hague University of Applied Sciences)

SUPERVISOR: Dr Michael Leveritt (PhD, School of Human Movements, University of Queensland)

Dear Participant,
Thank you for expressing interest in our study. Your participation will help us increase our knowledge on hydration practices of surfers and will enable us to make recommendations which will help to optimize hydration in surfers.

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the *National Statement on Ethical Conduct in Human Research*. Whilst you are free to discuss your participation in this study with project staff (contactable on contact number +61 490250930 or Email petrakoeb@aol.com). If you would like to speak to an officer of the University not involved in the study, you may contact Prof. Guy Wallis, the School of Human Movement and Nutrition Sciences Ethics Officer, on 3365 6180.

By signing this document you consent to being a participant in this study and agree with the following:

1. I have read and understood the information sheet.
2. I have had the possibility to ask questions and to have them answered.
3. I understand that the procedures of the study are independent from the surfing session and therefore surfing will be on my own risk.
4. I understand that participation in the study is voluntary and that I am free to withdraw at any time during the study without adverse consequences.
5. On the understanding that my name will not be used without my permission I agree to provide information to the researcher. The data obtained will only be used for this study and publications arising from this study and will be stored confidentially.

Name:……………………………………………………………………………………………….

Date:…………………………. Participant's signature:………………………………………

The participant was handed the information sheet by me and had the possibility to ask any questions concerning the study.

Date:…………………………. Researcher's signature:……………………………………..

APPENDIX 3: HYDRATION BEHAVIOUR QUESTIONNAIRE

Participant-nr.:

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

1. PERSONAL CHARACTERISTICS

Age ____________________

Height (in cm) ____________________

Gender ☐ Male ☐ Female

2. MEDICATION

Do you use any medications that alter fluid or electrolyte balance (e.g. diuretic medication?)

☐ Yes, I use the following (type of) medication ____________________

☐ No

3. SURFING HABITS

How much time do you usually spend in the water per session (in minutes)? ____________________

What is your surfing experience (in years)? ____________________

How often do you usually surf?

☐ Several times per week ☐ Once a week

☐ Several times per month ☐ Once a month

☐ Less than once a month

Do you take part in competitions?

- ☐ Yes, recreational competitions
- ☐ No
- ☐ Yes, professional competitions on national level
- ☐ Yes, professional competitions on international level
- ☐ Yes, other competitions

4. Hydration Behaviour

Do you normally ingest extra fluid *before* surfing in order to stay well hydrated?

- ☐ never
- ☐ Mostly
- ☐ sometimes
- ☐ Always

Do you normally ingest extra fluid *after* surfing in order to stay well hydrated?

- ☐ never
- ☐ Mostly
- ☐ sometimes
- ☐ Always

On a scale from 1 to 10, how important do you think hydration is for surfing performance?

	1	2	3	4	5	6	7	8	9	10	
Not important	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Very important

Thank you very much for completing the Questionnaire!

APPENDIX 4: INDIVIDUAL RESULTS OF THE FIELD STUDY

Participant-nr.	Results experiment: USG [g/ml]	Duration surfing session [min]	Weight loss [ml]	Sweat rate [L/h]	Sweat loss per hour [% BM]	Environmental conditions: Swell size [ft]	Water temp. [°C]	Air temp. [°C]	Results questionnaire: fluid ingestion before [1-4][1]	fluid ingestion after [1-4][1]	importance hydration [1-10][2]
1	1.022	100	-900	-0.54	-0.7	1-2ft	25	24	1	2	6
2	1.022	85	-100	-0.07	-0.1	2ft	26	25	2	4	4
3	1.020	50	-300	-0.36	-0.5	3-5ft	26	22	4	4	7
4	1.012	70	-1400	-1.20	-1.4	3-5ft	26	22	2	2	6
5	1.007	120	-200	-0.10	-0.1	6ft	25	23	3	3	10
6	1.023	60	-700	-0.70	-0.7	3-4ft	26	22	2	4	10
7	1.025	60	-300	-0.30	-0.4	3-4ft	26	22	3	4	8
8	1.022	60	-500	-0.50	-0.7	3-4ft	26	22	3	3	10
9	1.012	75	-100	-0.08	-0.1	2-4ft	26	25	4	4	10
10	1.015	80	-100	-0.08	-0.1	2-4ft	26	25	2	2	7
11	1.012	80	-100	-0.08	-0.1	2-4ft	26	25	3	4	7
12	1.015	80	-300	-0.23	-0.3	2-4ft	26	25	2	3	6
13	1.038	360	-2800	-0.70	-0.9	1-2ft	26	25	4	4	8
14	1.025	110	-800	-0.44	-0.7	2-3ft	26	23	2	2	8
15	1.018	65	-500	-0.46	-0.6	1-2ft	26	25	3	3	8
16	1.027	65	-500	-0.46	-0.5	1-2ft	26	25	3	4	8
17	1.020	50	-100	-0.12	-0.1	2-3ft	26	25	3	4	8
18	1.015	85	-500	-0.35	-0.5	2-3ft	26	24	4	4	10
19	1.007	120	-2700	-1.35	-1.9	2-3ft	26	23	2	2	10
20	1.025	120	-1400	-0.70	-1.1	2-3ft	26	23	3	3	8
21	1.020	120	-1400	-0.70	-1.0	2-3ft	26	23	3	4	10
22	1.025	45	-700	-0.93	-1.4	1-2ft	26	24	3	3	8

[1] 1=never, 2=sometimes, 3=mostly, 4=always; [2] 1= not important 10= very important

APPENDIX 5: PRACTICAL RECOMMENDATIONS

HYDRATION IN SURFERS

A FACT SHEET FOR DIETITIANS AND SURF COACHES

Key Facts:

- Surfing is a highly demanding sport requiring upper body aerobic endurance as well as upper and lower body muscular strength, jumping ability and excellent cognitive function.
- A dehydration level of 2-3% is likely to impair upper and lower body aerobic performance, upper and lower body muscular strength, cognitive function and will therefore affect surfing performance.
- There is a clear discrepancy between the knowledge about the importance of sufficient hydration for surfing performance and the information given on usual fluid intake before and after surfing: Although surfers seem to be aware of the importance of hydration for surfing performance 45% of the surfers were dehydrated at the start of their surfing session and 37% of the participants indicated that they drink extra fluids only “sometimes” or “never” before surfing.
- Dehydration at the start of the surfing session in combination with sweat loss can possibly lead to a dehydration level severe enough to impair surfing performance.
- Similar to studies in other disciplines, a wide range of data was obtained on sweat loss which highlights the need for individualized fluid-replacement guidance.
- Fluid replacement guidance should be individualized and based on the individual sweat rate of the surfer (under different environmental conditions and considering the type of clothing). Also, hydration guidance should aim at optimal hydration before surfing, preventing excessive dehydration while surfing and promoting rehydration after surfing.

Recommendations

Hydration before exercise:

According to the position statements of Casa et al. (2000) and Sawka et al. (2007) hydration before exercise should be initiated several hours before the exercise task to enable fluid absorption and allow urine production to return toward normal levels. Casa et al. (2000) advise to drink 500 ml about two hours prior to exercise, while Sawka et al. (2007) advise to start drinking 5-7 mL/kg bodyweight at least four hours before exercising and continue drinking another 3-5ml/kg bodyweight about two hours before exercising if the individual does not produce urine or the urine is intense yellow or highly concentrated. Those recommendations can be used as a guideline for surfers to promote good hydration before surfing.

Hydration during surfing:

Because the surfers would have to return to the beach to hydrate, fluid replacement during surfing is difficult. Therefore, the focus should be on optimal hydration prior to the surfing session and rehydration after surfing. Though, body weight reduction of more than 2-3% should be prevented with regard to surfing performance. The routine measurement of pre- and post- exercise body weight can be useful to estimate sweat rate and body mass loss under different conditions and give customized recommendations to the individual surfer about returning to the beach after a certain time in order to prevent a body weight reduction of more than 2-3% and promote optimal surfing performance. Though, returning to the beach for fluid replacement might not always be necessary, depending on the duration of the surfing session, sweat rate of the individual surfer and hydration status before surfing.

Rehydration after exercise:

Both position statements advise ingesting about 1.5 litres of fluid for each kilogram of body weight lost during exercise. The additional volume is recommended to compensate for the increased urine production following rapid consumption of large volumes of fluid. Also, in order to maximize fluid retention fluid should be consumed over time, if possible, instead of ingesting large boluses (Casa, 2000; Sawka, 2007).

Casa, D.J.; Armstrong, L.A.; Hillman, S.K.; Montain, S.J.; Reiff, R.V.; Rich, B.S.E., Roberts, W.O.; & Stone, J.A. (2000). National Athletic Trainers' Association position statement: fluid replacement for athletes. *Journal of Athletic Training*, 35, 212–224.

Sawka, M. N., Burke, L. M., Eichner, E. R., Maughan, R. J., Montain, S. J., & Stachenfeld, N. S. (2007). Exercise and fluid replacement. *Medicine and Science in Sports and Exercise, 39*(2), 377-390. doi:10.1249/mss.0b013e31802ca597