



## Hydration Status in Adolescent Alpine Skiers During a Training Camp

by

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*Maintaining euhydration is important for optimal health, performance and recovery, but can be challenging for alpine skiers when training in a relatively cold but dry environment. This study aimed to evaluate hydration status, fluid loss and fluid intake in adolescent alpine skiers during a training camp. Twelve athletes aged  $14.3 \pm 0.9$  years volunteered to participate in the study. Athletes resided at an altitude of 1600 m and trained between 1614 and 2164 m. During eight consecutive days, urine specific gravity was measured before each morning training session using a refractometer. Changes in body weight representing fluid loss and ad libitum fluid intake during each morning training session were assessed using a precision scale. Mean pre-training urine specific gravity remained stable throughout the training camp. Individual values ranged between 1.010 and 1.028 g/cm<sup>3</sup> with 50 to 83% of athletes in a hypohydrated state (urine specific gravity  $\geq 1.020$  g/cm<sup>3</sup>). Mean training induced fluid loss remained stable throughout the training camp (range -420 to -587 g) with individual losses up to 1197 g (-3.5%). Fluid intake was significantly lower than fluid loss during each training session. To conclude, urine specific gravity values before training indicated insufficient daily fluid intake in more than half of the athletes. Furthermore, fluid intake during training in adolescent alpine skiers was suboptimal even when drinks were provided ad libitum. Coaches and athletes should be encouraged to carefully monitor hydration status and to ensure that alpine skiers drink sufficiently during and in between training sessions.*

**Key words:** alpine skiing, dehydration, youth, fluid intake.

### Introduction

Fluid intake is of utmost importance for any athlete's health, performance and recovery from training and competition. When fluid intake cannot cover fluid losses, dehydration occurs which leads to a state of hypohydration, i.e., an insufficient total body water volume, intracellular fluid volume and an increased plasma osmotic pressure (Kenefick and Cheuvront, 2016). Even a small degree of dehydration, i.e., 1% of body weight, could increase whole body carbohydrate oxidation and muscle glycogenolysis during endurance exercise (Logan-Sprenger et al., 2012). The detrimental effects of dehydration and hypohydration have been thoroughly studied, mainly when exercising in hot environments where (mild) dehydration is known to impair

aerobic performance in particular (Bardis et al., 2013; Edwards et al., 2007; González-Alonso et al., 1997; Sawka, 1992). However, whether insufficient fluid intake and hypohydration would affect alpine skiing performance is still unknown (Meyer et al., 2011).

Alpine skiing is a high-intensity intermittent sport that relies on both anaerobic and aerobic energy systems (Turnbull et al., 2009). Alpine skiers often reside, train and compete at moderate to high altitudes, an environment often characterized by cold and dry air. These environmental conditions can lead to increased respirational water loss, reduced thirst perception and increased need to urinate (Meyer et al., 2011; O'Brien et al., 1998). Moreover, racers often avoid drinking much while on the slopes because of

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practical reasons (e.g., few restrooms), resulting in voluntary hypohydration (Burke, 2009; Meyer et al., 2011).

Since both hypohydration and dehydration negatively affect performance, the pre-training hydration status is of utmost importance due to the limited drinking possibilities or drinking avoidance during alpine ski training. Equally important is re-hydrating during recovery because a decreased intracellular fluid volume is reported to impair glycogen and protein resynthesis (Keller et al., 2003; Murray and Rosenbloom, 2018). Furthermore, when alpine skiers are at a training camp with daily training sessions, any fluid deficit that incurs during one training session can potentially compromise recovery and consequently the next training session if fluid is inadequately replaced.

Research on fluid intake and hydration status in alpine skiers is scarce. The study of Seifert et al. (2006) focussed on one day of recreational skiing, which is not representative for alpine skiers training for competition. To our knowledge no multiple-day studies on hydration status have been performed yet in adolescent alpine skiers. Therefore, this study evaluated hydration status in adolescent alpine skiers during an 8 day training camp, by formulating 3 research aims.

First, we aimed to evaluate hydration status before each morning training session. Secondly, we aimed to determine fluid loss during training sessions. The third aim was to evaluate if ad libitum fluid intake could compensate fluid loss during training.

## Methods

### Participants

In cooperation with the national alpine ski federation, skiers selected for the national youth squad and their parents were informed about the study and invited to participate. An informed consent form was signed by the athlete and his/her parents or guardians in accordance with the Declaration of Helsinki. The study and the consent procedure were approved by the university's Medical Ethical Committee.

Twelve athletes (3 girls and 9 boys) aged  $14.3 \pm 0.9$  years volunteered to participate in the study. Mean body mass was  $55.5 \pm 9.7$  kg and mean body height was  $165.9 \pm 6.9$  cm.

### Measures

Each athlete underwent a series of measurements before (between 8.30 and 9.00 a.m.) and immediately after each morning training session (around noon). No data were derived from the afternoon training sessions because of lack of time and comfort reasons regarding the athletes. On days 5 and 8 there were no morning training sessions. On these days, only Urine Specific Gravity (USG) was determined at about the same hour as on other days.

To evaluate hydration status before each morning training session, participants provided a spot urine sample in order to measure USG using a portable refractometer (ATAGO®, Japan). The following categories were used to classify the hydration status: *euhydrated* ( $USG < 1.010 \text{ g}\cdot\text{ml}^{-1}$ ), *minimally hypohydrated* ( $USG 1.010\text{--}1.019 \text{ g}\cdot\text{ml}^{-1}$ ), *hypohydrated* ( $1.020\text{--}1.029 \text{ g}\cdot\text{ml}^{-1}$ ) and *severely hypohydrated* ( $USG \geq 1.030 \text{ g}\cdot\text{ml}^{-1}$ ) (Casa et al., 2000).

Body weight and the weight of the athletes' personal drinking bottle they took with them on the slope were measured pre- and post-training using a high precision digital platform scale with accuracy of 2 g (Allscales®Europe, Henk Maas® scales, The Netherlands). Body weight was determined with participants only wearing thermal underwear or normal underwear. In each case the pre- and post-training measurement was performed in the same outfit to eliminate bias.

Net change in body weight during each training session was calculated by subtracting post-training body weight from pre-training body weight. Fluid loss during each training was calculated by correcting net change in body weight for total fluid intake (pre- minus post-training weight of the drinking bottle).

$$\text{Net change in BW (g)} = \text{Pre-training BW (g)} - \text{post-training BW (g)}$$

$$\text{Relative net change in BW (\%)} = (\text{net change in BW (g)} / \text{pre training BW (g)}) \times 100$$

$$\text{Fluid loss (g)} = \text{net change in body weight (g)} + \text{fluid intake (g)}$$

$$\text{Relative fluid loss (\%)} = (\text{fluid loss (g)} / \text{pre training BW (g)}) \times 100$$

### Design and Procedures

Data were collected during a training camp in the ski domain Les Arcs, France, from December, 19<sup>th</sup> to December, 26<sup>th</sup>. Athletes resided at an altitude of 1600 m. Athletes were woken at 7.15

a.m. and had breakfast between 7.30 and 8.00 a.m.. From 8.00 to 8.30 a.m. they prepared for training (i.e. gathering equipment, preparing drinking bottles). The training track was located at an altitude of 1614 to 2164 m. Only on day 5 the altitude ranged from 1614 to 2695 m. Temperature and air humidity were determined every day using the online information of 'Météo les Arcs' (<http://www.lesarcs.com/meteo.html>). Table 1 gives an overview of training characteristics and environmental conditions during the training camp. On most days, training sessions took place in the morning as well as in the afternoon. On days 5 and 8 there were no morning training sessions. In the evening of day 5 a training session focused on strength and endurance (climbing stair exercises) took place. On the 7<sup>th</sup> and 8<sup>th</sup> day, 2 participants refrained from training. One because of painful complaints about the hamstrings and one because of illness.

Duration of slalom training sessions was between 2 h 50 min and 3 h and giant slalom sessions took approximately 2 h 45 min. The duration of the free skiing session on day 5 was 2 h 30 min. Athletes left their backpacks with their drinking bottles inside at the top of the training track, except during the free skiing session when they carried their drinking bottle with them.

#### Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 25.0 software (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Normal distribution of the data was assessed using the Kolmogorov-Smirnov test. The percentages of euhydrated, minimally hypohydrated and hypohydrated participants on each day were calculated using the pre-determined cut-off values. To compare between days, repeated measures ANOVA procedures with Bonferroni corrections were applied on USG, fluid loss and fluid intake during training. To evaluate if fluid intake could compensate for fluid loss, both variables were compared with paired sample *t* tests on each day. All data are reported as mean  $\pm$  standard deviation and the level of significance was set at  $p < 0.05$ .

## Results

Table 2 provides an overview of daily values for USG, fluid loss and fluid intake.

As illustrated in Figure 1, pre-training

USG values remained stable throughout the training camp ( $p = 0.737$ ) and ranged between 1.010 and 1.028 g/cm<sup>3</sup> with 50% (day 1) to 83% (day 7) of athletes starting the training session in a hypohydrated state (USG  $\geq 1.020$  g/cm<sup>3</sup>). None of the athletes exceeded USG values of 1.030 g/cm<sup>3</sup>.

Fluid loss during training was comparable throughout the training camp with individual losses up to 1197 g (-3.5% relative fluid loss) and was in most cases only partly countered by fluid intake with individual values ranging between 0 and 859 g. During each morning training, mean fluid loss was significantly higher than fluid intake, as illustrated in Figure 2. On average, this resulted in relative net weight changes between  $0 \pm 0.5\%$  and  $-0.5 \pm 0.7\%$ . On the individual level, net weight changes ranged between -1.5% and +1.5%.

ANOVA revealed that on day 7, fluid intake was significantly lower than on days 1, 2, and 3 (all  $p \leq 0.001$ ).

## Discussion

This study, with an 8-day follow-up of alpine skiers who maintained their normal activities in their habitual training camp, had a high ecological validity. As a consequence, this study brings new insights into hydration status during, but also in between training bouts, in a population that until now has been under-studied. The results showed that none of the adolescent alpine skiers' pre-training USG values were optimal ( $< 1.010$  g/cm<sup>3</sup>) during the training camp and on average these athletes started each morning training session in a hypohydrated state (USG  $\geq 1.020$  g/cm<sup>3</sup>). This consistency in suboptimal USG findings raises concern considering the potential detrimental effects on health, recovery and performance (Keller et al., 2003; Kenefick and Cheuvront, 2016; Sawka, 1992). It should be kept in mind that this study used pre-exercise USG and changes in body weight from pre- to post-exercise to determine the hydration status, which is in accordance with customary guidelines to assess hydration status in athletes (Armstrong et al., 1998; Hamouti and Mora-Rodriguez, 2013). However, it should be recognized that more accurate hydration assessment techniques based on plasma osmolality and haematocrit exist, but these require blood samples, a high level of expertise and are relatively expensive which make them

less suited for field studies (Armstrong et al., 1998; Armstrong, 2005). Still, blood samples would have allowed to evaluate if elevated USG values indeed represented too low body water volumes (i.e., hypohydration) or not. Indeed, maintenance of body water homeostasis through water saving hormonal effects of vasopressin is also accompanied with higher urinary biomarkers

for dehydration (Kavouras, 2019), a phenomenon already observed in combat athletes (Zubac et al., 2018). If this was also the case in alpine skiers participating in the present study, it would be more appropriate to classify them as being 'underhydrated' instead of being 'hypohydrated' (Kavouras, 2019).

**Table 1***Training characteristics and environmental conditions during the study period*

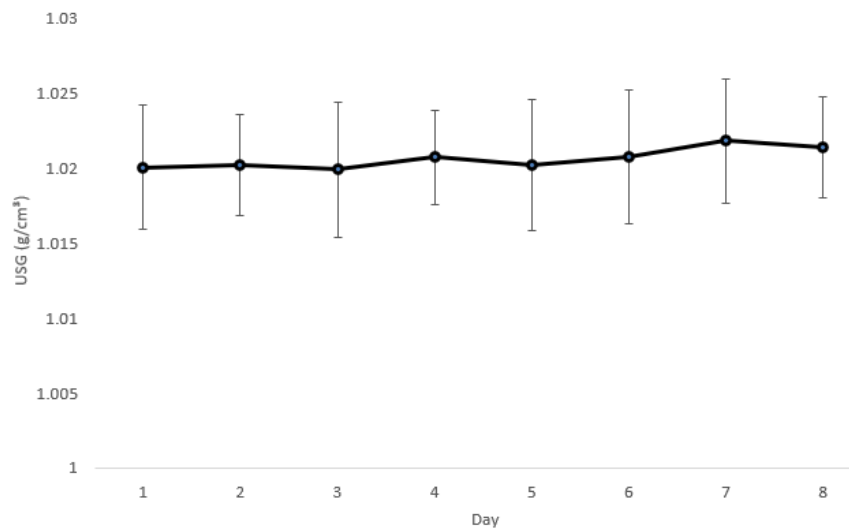
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Minimum T (°C)	-2	1	2	1	2	-1	-2	-1
Maximum T (°C)	7	8	7	4	8	6	5	7
Air humidity (%)	70	67	74	77	65	62	59	46
Morning training	GS	GS	SL	SL	/	SL	SL	/
Afternoon training	GS	GS	GS	GS	FS	SL	SL	SL

*T = Temperature; SL = Slalom; GS = Giant Slalom; FS = Free Skiing*

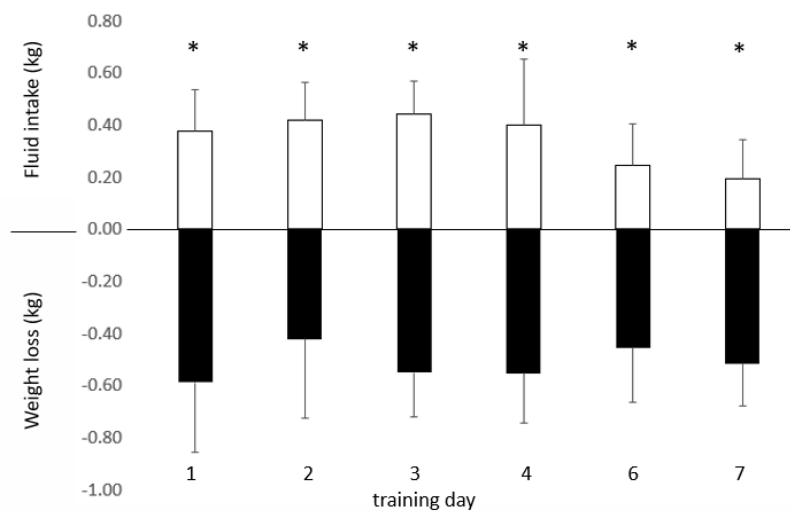
**Table 2***Overview of daily measurements presented as mean (SD)*

	Day 1	Day 2	Day 3	Day 4	Day 5 <sup>a</sup>	Day 6	Day 7	Day 8 <sup>a</sup>	<i>p</i>
USG	1.020 (0.004)	1.020 (0.003)	1.020 (0.005)	1.021 (0.003)	1.020 (0.004)	1.021 (0.005)	1.022 (0.004)	1.021 (0.003)	0.737
Fluid loss (g)	-587 (270)	-421 (301)	-550 (170)	-553 (189)	/	-454 (211)	-515 (164)	/	0.239
Fluid loss (% of BW)	-1.4 (0.9)	-0.8 (0.8)	-1.0 (0.5)	-1.2 (0.6)	/	-1.2 (0.6)	-1.6 (0.6)	/	
Fluid intake (g)	376 (159)	421 (146)	445 (123)	401 (251)	/	245 (163)	194 (148)	/	<0.001
Net BW change (%)	-0.3 (0.5)	-0.0 (0.5)	-0.2 (0.3)	-0.3 (0.4)	/	-0.2 (0.7)	-0.5 (0.7)	/	0.239
RPE	13.4 (1.4)	13.9 (1.5)	15.7 (1.6)	14.3 (1.4)	/	13.6 (1.8)	14.3 (0.9)	/	0.002

*<sup>a</sup>: no morning training session; USG: Urine Specific Gravity; BW: Body weight;  
RPE: Rate of Perceived Exertion*



**Figure 1**  
Daily pre-training USG values during a training camp (means and standard deviations)



**Figure 2**  
Fluid intake versus weight loss during training (means and standard deviations)  
\*: fluid intake significantly lower than weight loss,  $p < 0,001$

Fluid losses during training were not extreme, but the average fluid intake could not compensate for fluid losses as the net average change in body weight ranged between 0 and 0.5%. High inter-individual variability was observed for both fluid loss and intake during training sessions and it is worth mentioning that on some days, some athletes did succeed in compensating fluid loss by fluid intake during training, or even over-compensated on a rare occasion. A study by Bargh et al. (2017) showed that rugby players tended to drink in excess of fluid loss when performing in a cold environment. However, these rugby players had demarcated drinking pauses, which was not the case in the present study.

Consuming more fluid than necessary can result in hyperhydration, which can also have unfavorable effects and should be avoided as well. When the fluid is low in electrolytes, hyperhydration gives an increased risk on hyponatremia by diluting and lowering plasma sodium (ACSM, 2007). It can also induce the need to empty the bladder during exercise (Freund et al., 1995; O'Brien et al., 2005), which can be quite inconvenient when athletes are on the slope and toilet accommodations are not close (Burke, 2009). However, an increase in body weight may also indicate a restoration of body fluid in those who started the training session in a state of hypohydration.

In a review by Kenefick (2018), it is suggested that drinking by thirst may be sufficient when activities are performed in a cool environment, and when they are of relative short duration (< 90 min). In the present study, training duration was around 180 minutes, and even though in a cool environment, drinking by thirst and ad libitum fluid intake could not prevent a certain degree of dehydration. On day 7, fluid intake was significantly lower than on the first 3 days of the training camp. Besides a somewhat lower air humidity on day 7, no noteworthy meteorological phenomena were observed and there were no other specific events remarked that could explain this difference.

To the best of our knowledge, hydration status in adolescent alpine skiers has not been studied longitudinally before, but studies in other sports disciplines confirm that fluid intake in adolescent athletes is often a concern (Buoite

Stella et al., 2017; Chapelle et al., 2017; Kiitam et al., 2018; Nuccio et al., 2017). In comparison to values found in the literature, average USG values did not indicate severe hypohydration, whilst the observed decrease in body weight in the present study remained relatively low. Although data were collected late December and training sessions were relatively long in duration, environmental conditions during the training camp were moderate. The relative high air humidity and not too extreme cold did not provoke severe dehydration. Therefore, it can be assumed that negative effects of hypohydration and dehydration on training performance remained limited under the circumstances of the present study, since even aerobic capacities do not seem to decline when dehydration is less than 3% BW while performing in cold environments (ACSM, 2007). However, a higher altitude, lower temperatures and dryer air could have provoked more pronounced respirational water loss, cold-induced diuresis and impaired thirst (Meyer et al., 2011; O'Brien et al., 1998). At the same time, extreme cold can cause beverages getting too cold or even freeze, making it a challenge to consume them. Such conditions would cause more severe dehydration and could potentially lead to impaired cognition, aerobic capacities, volitional peak force, and muscle cramps (ACSM, 2007; Minshull and James, 2013). The latter was observed to occur in dehydrated cross-country skiers and ice-hockey goalies, also typically performing in a cold environment. These effects on performance may also occur in alpine skiers especially when they are over-dressed against the cold. Since alpine skiers train continuously for several hours, during which they need to remain fully focused while relying on aerobic and anaerobic capacities as well as specific skills including agility, severe dehydration may not only affect performance, but can also put these athletes at a higher risk for high-speed crashes and injury (Steidl-Müller et al., 2020).

A limitation of the present study is that the type of fluid was not analyzed, and information is lacking on carbohydrate and electrolyte composition. This is important to maintain blood glucose and electrolyte levels as well as for muscular carbohydrate uptake. A second limitation is the lack of performance or muscular recovery measures. Such measures

would be interesting to see if mild dehydration in alpine skiers has a significant effect on ski performance and muscular recovery. Future studies applying a randomized controlled trial are necessary to answer these questions. Thirdly, fluid intake was monitored during training, but not in between training sessions because of practical reasons. Therefore, we do not know the contribution of (excessive) fluid losses nor (inadequate) drinking and dietary habits in between training sessions to the observed suboptimal USG values. A detailed knowledge on food and fluid intake behavior during and in between training sessions would be interesting to determine the needs for optimal performance, recovery and preparation for the next training session.

The important role of the coach in encouraging athletes to drink has been recently confirmed (Buoite Stella et al., 2017). Therefore, coaches of adolescent alpine skiers should be informed about the importance of optimal hydration, and they should be aware of the responsibility they have in achieving this. Besides providing enough drinking possibilities, also nearby toilet accommodation can help improve hydration status during training sessions. Making sure that athletes sufficiently drink in between training sessions is also important although this may be less evident to establish for coaches. If possible, the substrate content, mineralization and

alkalinity of the beverages consumed should be taken into account as well, as these properties also play a role during recovery from exercise (ACSM, 2009; Chycki et al., 2017). Furthermore, alpine skiers competing at an international level regularly have to travel by plane to reach locations of competitions. During these long-haul flights they are exposed to the typical dry air and air pressure in the aircraft cabin, similar to being at a moderate altitude. This way they are at risk for arriving at their destination already in a hypohydrated state (Reilly et al., 2007). Thus, maintaining euhydration should already be focused on during travelling, to ensure optimal preparation for a prolonged stay in a challenging environment.

To conclude, USG values before training indicate insufficient daily fluid intake in more than half of the athletes. Furthermore, during training adolescent alpine skiers can experience substantial fluid loss which in most cases is not entirely replaced by fluid intake, even when drinks are provided ad libitum. Therefore, athletes' hydration status should be carefully monitored, and they should be encouraged to drink sufficiently during and in between training sessions. Pointing coaches at their responsibility in achieving optimally hydrated athletes is recommended.

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