Free hydration and well-being during physical education in tropical climate

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Background : Strategies for physical education (PE) classes in tropical climate are needed to optimize health outcomes. We hypothesized that ergonomic strategies using free hydration during PE would positively impact the physical activity and well-being of children.

Methods : Forty-eight 13- to 15-year-old students participated in two randomized PE lessons. In one lesson, students were in sprint or long jump/pole vault workshops and the teacher regulated hydration (L_{REGUL}). In the other, they could freely hydrate after their sprint or jump/vault performances (L_{FREE}). Lessons lasted 80 min, with mean temperature : 27.2±0.5 °C and rh : 80±4.3 %. Working activity (WA) per student was assessed in each condition. Tympanic temperature, water intake and weight loss were measured

before and after each lesson while rating of perceived effort (RPE) was assessed at lesson end.

Results : Video analysis revealed four types of non-working activity (NWA) : sitting, horseplay, going to drink and teacher interactions. WA was +48.6 % and NWA was -26.8 % during L_{FREE}. RPE was scored as "rather light effort" with no difference between conditions for tympanic temperature, water intake or weight loss.

Conclusions : We demonstrated that students' physical activity can be significantly increased in tropical PE lessons when the ergonomic strategy of individualized hydration is applied, whereas student well-being is not affected. This strategy helps to (1) optimize physical activity and (2) reduce the consequences of thermal stress on health.

Key words : ergonomics, health, student, South Pacific, Oceania.

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1 Introduction

Physical education (PE) is the main outdoor school discipline, and it is climate-dependent (Somboonwong *et al.*, 2012). Teaching PE in cold, hot-dry, and hot-wet climates differs, as each climate presents peculiarities that need to be taken into account to optimize students' acquisition of motor and intellectual skills. Teaching PE in Oceania (South Pacific) presents particular challenges (Galy & Monnier, 2006) because of a unique tropical climate : temperatures around 26 °C and 60 % relative humidity (rh) for the cool season and 35 °C and 100 % rh for the hot season.

It is widely acknowledged that aerobic performance is significantly altered in tropical environment compared with neutral environment (Voltaire *et al.*, 2002 ; Hue, 2012a,b) even for natives (Voltaire *et al.*, 2003). The environment imposes several constraints on outdoor PE lessons, such as sun, wind, rain, and the shortage of water sources, all with consequences for student well-being (Bar-Or, 1998 ; Hue, 2012a,b), including the fatigue that they may experience before, during and after these lessons. Regular physical exercise provokes symptoms of physiological and/or psychological fatigue in teenagers, sometimes in connection with the context of the class, which is reflected by a nonchalant attitude and/or a lack of appetite for the physical practice (Sallis *et al.*, 2000). However, as these symptoms appear before or during PE, they are often confused with student "motivation" (Schmidt & Wrisberg, 2008). Indeed, non-working activities often arise during PE lessons : the students sit down, want to drink, look for shade, and horse around. The teacher's interventions thus increase and all reduces physical activities/learning (Durand, 1996). However, when students in a tropical environment say they are "tired" during or at the end of PE lessons, they are not simply expressing a lack of motivation. Indeed, motivation can be defined as the process that determines the direction and energization of behavior (Elliot, 2006). The direction expressed by self-involvement describes the settings in which individuals' performance has consequences and implications (Gendolla, 2004). Complementary effort is defined as the mobilization of resources to carry out instrumental behavior (Gendolla & Wright, 2009) ; it therefore refers to the intensity of motivation. PE lessons conducted in tropical climate might increase the psycho-physiological stress of students and impact both the direction and energization of behavior, thereby affecting

their working activity. The tiredness may very well be physiological in part, linked to the stressful thermal and environmental conditions that characterize PE lessons conducted in a hot-wet environment. In fact, the stress of the tropical environment may be greater than the endogenous stress of the exercise. Somboonwong *et al.* (2012) even suggested that "teachers should allow students to have frequent drinking breaks and prepare modified play-to-rest ratios as well as inclusion of more shaded or ventilated areas". It thus seems important to understand how fatigue arises so that ergonomic adaptations can be proposed to ensure tropically adapted PE lessons.

The aim of this study was therefore to test whether hydration during PE lessons in a hot-wet environment has an impact on students' global activity (physical and non-physical activities) and well-being during the lessons in two conditions : (1) hydration only when the teacher has students rotate between workshops and (2) free hydration in the workshops so that students can hydrate at their convenience during the working phases.

2 Methods

2.1 Subjects

Two classes of 24 children, with ages ranging from 13 to 15 years old, participated in this study, including 24 girls and 24 boys. Lots were drawn in each class of the fourth level of middle school. All these children had 3 hours of physical education per week. Fifteen students practiced personal sports in addition to PE, for a mean weekly practice of 4 hours and 50 minutes. The children were without histories of pulmonary or cardiovascular disease. During the first PE lessons, they were familiarized with the stadium used for the experiment.

2.2 Measurement

2.2.1 Physical and non-physical activity

Two digital cameras (SONY, Digital video, GR DV 3000, Japan) recorded the lessons. The first camera was placed in the stands 150-m from the students and was set for a wide angle view to keep the whole class in sight. This distance also helped the students to forget the camera during the lesson. The second camera was placed perpendicular to the first at ground level (1-m) ; it was close to the class activity to enable combined sound and image analysis, mainly of NWA.

The video recordings during L_{REGUL} and L_{FREE} were analyzed by two experts. These data were included in the analysis of student motor activity, with working activity (WA) expressed by a single sprint or a single long jump/pole vault. The intensity of each physical activity, which started with skill practice, followed by playing sports, was determined by the metabolic equivalent of task (MET) value using the compendium of energy expenditures for youth given by Ridley *et al.* (2008).

Individual WA per student and per lesson in each condition was calculated on the basis of the teacher's notes and the video recordings. Similarly, the non-working activity (NWA) expressed actions in relations with : (1) going to drink, (2) sitting down, (3) playing around, and (4) interactions with the teacher.

2.2.2 RPE and questionnaire of well-being

The Borg scale (1973) was used to assess the students' rating of perceived effort (RPE) during the PE lesson. At the end of every lesson, students were also individually questioned (Tab1) based on a set of questions on well-being and fatigue. The items dealt with feelings of fatigue, students' actions to deal with this fatigue, states of hyperthermia and dehydration, and the overall sense of well-being (Tab1). Item questions were randomly asked.

2.2.3

Tympanic temperature (T_{tym}, °C) was recorded before exercise and immediately at the end of exercise in the ear using a thermometer (Omron MC 520, Hoofddorp, the Netherlands) that measures infrared temperature generated by the eardrum. Since the tympanum shares a common blood supply with the hypothalamus, T_{tym} has been proposed as a surrogate measure of hypothalamic temperature. In fact, Bricknell (1997) evaluated infrared thermometry for thermal physiology research and demonstrated that the slope of the regression line between tympanic temperature and core temperature measurements was 0.9967 with a correlation coefficient of 0.706. It was also shown to be accurate enough to evaluate temperature changes during field trials (Bricknell, 1997). In the present study, the T_{tym} was measured by the same investigator.

2.2.4

Water intake was measured using a batch of 600-ml bottles of water. Each student received a bottle with their name on it to be used without encouragement during exercise. They were allowed to refresh their faces at one of the three fountains near the workshop, but they were only allowed to drink from their personal bottle. At the end of the exercise, the total fluid intake was measured.

2.2.5

Body mass loss (kg) was measured on a scale by changes in body mass (+ 1.10^{-1} kg) (Tanita HA 503, Tanita Corporation, Tokyo, Japan). Each student was weighed before and after lessons wearing only underwear after sweat was wiped from the body. Sweat loss was calculated from the change in body weight plus total fluid intake minus urine output (none of them urinated in either condition). Sweat rates were then determined as sweat loss per unit of time (milliliters per hour).

2.3 Procedure

Two PE lessons for each class were conducted, filmed and analyzed [Fig1] by an independent investigator in an outdoor sports stadium with the international agreement of the Fédération française d'athlétisme (French Norm, European Norm N° 14877 and French Norm N° P90-100). Track and field activities were chosen mainly for their reproducibility. Also, the stadiums are standardized around the world and we assumed our interpretations would not be weakened by activity or place bias. The experimental lessons were the third and fourth lessons of a scheduled program of nine lessons. The first two lessons were used to determine the two group levels within each class, to explain the objectives of the track

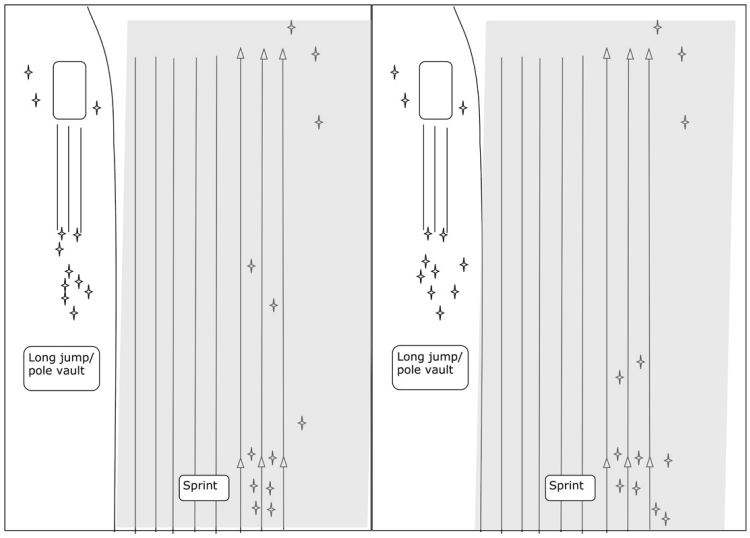


FIGURE 1 – Ergonomics of each lesson. Left side : workshop without drinking at water point. Right side : workshop including drinking at water point. Crosses represent students.

and field cycle, and to determine the workshop organization for the 50-m sprint, the long jump, and the pole vault. Students were taught pole vaulting in the same sandbox as the long jump. The experimental lessons were randomly conducted in the two classes. The PE teacher was aware of the experimental design throughout the study period. L_{REGUL} was organized into two workshops that divided the class into two levels, as determined in previous lessons. The PE teacher gave permission to hydrate between every sequence (*i.e.* the time spent in the workshops) of the lesson. The students could stand in the shade zones as shade made up half of the lesson area, as can be seen in [Fig1]. The students were also allowed to sit. L_{FREE} was also organized into two workshops according to the same procedures as in L_{REGUL}. The students were free to hydrate on their return to the starting point after their sprint, long jump or pole vault performance [Fig1]. As in the first lesson, students could seek out shade zones and sit down. Both the L_{REGUL} and L_{FREE} lessons were conducted between 2 pm and 4 pm in the hot season. Every lesson lasted 80 minutes.

The subjects performed a 5-minute general warm-up consisting of low- to moderate-intensity aerobic exercise followed by a series of five circuits, including 20-m of forward jogging, 20-m of sidestepping, and 20-m of jogging backwards, then by 5 minutes of a designated stretching protocol, and finally an explosive-force warm-up consisting of five to seven incremental intermittent 20-m sprints. It is common practice for athletes to finish the warm-up with high-intensity sport-specific activities to both physiologically and psychologically prepare for the subsequent activity (Young & Behm, 2002). After this 10-minute warm-up, the students had 2 minutes to drink as much water as they liked (personal bottle). Next, the teacher spent 3 minutes organizing the class into workshops, giving out assignments, and answering questions. Then, the students went to their workshops and had 20 minutes for their tasks in the sprint or long jump/pole vault. Sprint and jump

performances were measured by two experimenters using a manual chronometer and a decameter, respectively. For all the lessons, the weather was generally sunny with some cloudy spells. The temperature was 27.2±0.5 °C with an rh of 80.1±4.3 %.

2.4 Analysis

The results are expressed in mean values ± standard deviation. After verification of the normality of distribution, all the data (field performance, individual working activity, Borg score, T_{tym}, weight loss) were compared between the lessons (regulated or free hydration) using two-way ANOVA. Proportions of NWA and WA and types of NWA were compared across hydration modalities using Chi^2 tests.

The statistical analysis was performed with Systat Version 5.01 (Systat, Inc., Evanston, IL, USA). Significant results were established with $P<0.05$. The questionnaire responses were not statistically analyzed but instead served as a rough guide.

3 Results

Tableau 1 – Responses to the series of questions on global fatigue linked to PE and expressed in percentage (%).

	YES (%)	NO (%)	SOMETIMES (%)
Do you feel good in PE ?	75	12.5	12.5
Do you feel tired during the day ?	33.3	25	41.6
When you feel tired, do you tell your teacher ?	35.4	56.2	8.3
When you feel tired, do you sit off to the side in PE ?	8.3	62.5	29.1
Do you get hot in PE ?	62.5	8.3	29.1
When you feel hot, does this stop you from continuing your PE task ?	12.5	62.5	25
Do you get thirsty in PE ?	83.3	4.1	12.5
When you drink, do you feel better ?	83.3	4.1	12.5
Do you have a headache after PE ?	0	75	25
Do you have a headache during PE ?	8.3	54.1	37.5

The questionnaire presented in the table 1 shows that 75 % of the students reported a feeling of general well-being in PE class. The effects of school-day fatigue were noted in 33 % of them. During the PE lessons, 63 % were negatively affected by the heat, 83 % reported feeling thirsty, and when they drank 83 % said they felt better.

Tableau 2 – The mean non-working activity (NWA) per student during L_{REGUL} and L_{FREE}, detailed for sequence 1 (sprint or long jump/pole vault) and sequence 2. Number of individual NWA are detailed as : total NWA, sitting down, horseplay, interactions with teacher, and going to drink. * Significantly different compared with L_{REGUL}, P<0.01. $ Significantly different in the distribution of NWA between sequences and water hydration compared with L_{REGUL}, P<0.001.

	NON-WORKING ACTIVITY				
	Total	Sitting down	Horseplay	Interactions with Teacher	Go drinking
During L_{REGUL} sequence 1 (sprint or long jump/pole vault)	2.41	0.95	0.41	0.04	1.00
SD	0.01	0.02	0.02	0.01	0.01
During L_{REGUL} sequence 2 (sprint or long jump/pole vault)	1.62	0.41	0.62	0.21	0.37$
SD	0.02	0.01	0.4	0.02	0.01
During LREGUL	4.04	1.37	1.04	0.25	1.37
SD	0.01	0.02	0.02	0.01	0.01
During L_{FREE} sequence 1 (sprint or long jump/pole vault)	0.66 *	0.20	0.01*	0.17	0.29*
SD	0.02	0.01	0.4	0.02	0.01
During L_{FREE} sequence 2 (sprint or long jump/pole vault)	2.29 *	1.25	0.20*	0.21	0.62*
SD	0.01	0.02	0.02	0.01	0.01
During LFREE	2.95 *	1.45	0.20*	0.38	0.91 *
SD	0.02	0.01	0.4	0.02	0.01
% calculated in L_{FREE} compared to L_{REGUL}	"-26.80"	6.06	"-80.00"	50.00	"-33.33"

The table 2 shows significantly fewer total NWA, water hydration NWA, and horseplay NWA in L_{FREE} compared with L_{REGUL}. During L_{REGUL}, total NWA per student was significantly affected in sequence 2 compared with sequence 1, $P<0.001$. In sequence 2 of L_{REGUL}, NWA was attributed to going to drink, $P<0.001$.

Tableau 3 – Mean values of working activity (WA) during L_{REGUL} and L_{FREE} expressed per student and lesson : total trials, sprints and long jumps/pole vault. * Significantly different compared with L_{REGUL}, P<0.05.

	Total	Sprints	Long jumps/pole Vault
Mean WA during L_{REGUL}	6.1	2.2	4.1
SD	0.1	0.1	0.3
Mean WA during L_{FREE}	8.9*	2.5*	6.4*
SD	0.2	0.3	0.3

The table 3 shows significantly more individual WA in L_{FREE} compared with L_{REGUL}, with 8.9±0.2 and 6.0±0.3, respectively, $P<0.001$. This indicates +48.6 % more global WA in L_{FREE} then L_{REGUL}.

Performance showed no significant differences, with 3.0±0.6 vs 3.0±0.6 meters for the long jump and 8.59±0.75 vs 8.57±0.72 seconds for the sprint in L_{REGUL} and L_{FREE}, $P<0.05$, respectively. Conversely, a significant increase in pole vault performance was noted in L_{FREE} compared with $L_{REGUL,}$ with 3.0±0.7 *vs* 3.2±0.7, $P<0.05$, respectively.

Tableau 4 – Exercise intensity, T_{tymp}, hydration status and rating of perceived exertion observed at L_{REGUL} and L_{FREE}. No significant observations were noted.

Parameters (N=48)	L_{regul}	L_{free}
Exercise intensity (METs)		
Skill practice	3	3
Pole vault/long jump or sprints	6 to 9	6 to 9
Ear temperature (°C)		
Pre-exercise	36.4 (0.3)	36.5 (0.4)
Post-exercise	37.1 (0.2)	37.3 (0.2)
Mean difference	0.65	0.65
Hydration status		
Sweat rate (ml/h)	451.4 (220.1)	460.9 (200.8)
% Loss of body weight	0.54 (0.2)	0.51 (0.3)
Climatic condition	27.0	27.4
Air temperature (°C)	32.8	32.9
Relative humidity (%)	78.2	82.3
Rate perception exertion		
Borg score	10.9 (2.0)	11.2 (1.8)

The parameters are shown in the table 4. No significant differences were observed between conditions or before and after L_{REGUL} and L_{REE} for exercise intensity, T_{tym} change, weight loss and hydration change. No significant difference was noted for RPE between lessons (Tab4), for which the students noted a "rather light effort" and a score of 10.9±2.0 and 11.2±1.8 for L_{REGUL} and L_{FREE}, respectively.

4 Discussion

This study shows that students' physical activity can be significantly increased in tropical PE lessons when the ergonomic strategy of individualized hydration is applied, whereas student well-being is not affected. This strategy helps to (1) optimize physical activity and (2) reduce the consequences of thermal stress on health.

Only a few studies have investigated the responses of children and adolescents acclimatized to a tropical environment during exercise (Rivera-Brown *et al.*, 1999 ; Rowland, 2008). Most studies of children's or pre-adolescents' responses to heat exposure have investigated briefly exposed non-acclimatized children/pre-adolescents or those acclimated for only a short time to a hot climate (Rowland, 2008). Boys in primary school exhibit adequate cardiovascular and thermoregulatory responses in PE class under hot-wet conditions during outdoor physical activity with an intensity of 2.5-9 MET and duration of about 30 min[1]. However, the risk for heat illness is increased, especially in overweight children and those with poor hydration status. The subjects of the present study were 13- to 15-year-old Oceanian students, without overweight and native to and living in New Caledonia, which has a tropical climate demonstrated to have deleterious effects on both adults (Hue, 2012a, b ; Voltaire *et al.*, 2003) and children (Hue & Galy, 2012).

4.1 Questioning students for a global approach to fatigue

"But I'm tired !" is a frequent complaint of PE students in a hot-wet environment, which is why we first opted for a questionnaire as a global approach to fatigue. The fatigue questionnaire was proposed to all students one month into the school year (Tab1). While 75 % of the students felt good in PE, fatigue was experienced during the course of the school day by 33 % and sometimes by 42 % of the students. The organization of the school day with regard to student biorhythms needs to be noted : students attend school 5 days per week, beginning at 7 am and ending at 4 pm. The classrooms are not ventilated, air-conditioned or shielded from the sun, which contributes to student fatigue in a tropical environment. During the PE lessons, 63 % were hot, 83 % were thirsty, and 13 % frequently stopped their task-oriented activities, had difficulties expressing themselves during PE exercises, or ended these learning activities prematurely to seek out shade zones or horse around. Interestingly, when they drank during the lessons, 83 % immediately felt better. After the PE lessons, 8 % reported headaches and 37 % reported sometimes having a headache or feelings of difficulty, fatigue, and persistent tiredness (Tab1). The impact of the tropical environment seems evident, particularly regarding physical activity, as recently suggested by Somboonwong *et al.* (2012).

4.2 Physical activity during L_{REGUL} and L_{FREE}

Compared with L_{REGUL}, L_{FREE} was characterized by greater physical activity, with 48.6 % more WA. The high degree of humidity in the tropical (*i.e.* hot-wet) environment does not permit adequate evaporation (Bar-Or, 1998). Thus, when the environmental evaporative capacity is limited, using the strategy for a hot/dry climate (*i.e.* reducing heat storage by increasing the sweating rate) creates a physiological disadvantage that results in severe dehydration. This process needs to be taken into account for both conditions in the present study, but it cannot explain the significantly lower global efficacy in L_{REGUL}, which showed significantly fewer WA compared with L_{FREE} (Tab3). One might assume that the mean difference in WA reflected diminished motivation and/or an inability to maintain the same workload in the L_{REGUL} and L_{FREE} trials. Yet a drop in WA for the second trial can easily be rejected, whether objectively or subjectively evaluated, since the trials were randomized. The subjective assessment of intensity may have influenced WA. However, this subjective intensity, evaluated by the Borg scale at the end of each trial, did not show significant differences within or between trials, with 10.9 ± 2.0 and 11.2 ± 1.8 for L_{REGUL} and L_{FREE}, respectively. The plausible explanation for the difference in WA is that the students were unable to maintain the same level of activity during the L_{REGUL} trial for both objective and subjective reasons. As recently demonstrated for the use of oral adjuvant during exercise in the heat (Mundle *et al.*, 2006), working under L_{FREE} conditions during PE may be a pleasanter and more rewarding/motivating experience in the brain, therefore extending the exercise capacity.

We therefore suggest that the higher motivation induced by free hydration during L_{FREE} had a positive impact on the effort behavior (Gendolla & Wright, 2009), which refers to the intensity of motivation. In their review, Gendolla and Richter (2010) showed that the principles of motivational intensity theory apply to performance conditions that have direct consequences for self-definition, self-esteem and well-being. During $L_{FREE,}$ free hydration may have decreased the psycho-physiological stress of the students and positively affected the effort of behavior, thereby increasing WA and reducing NWA compared with L_{REGUL}. This observation also reveals the importance of considering the ergonomics of tropicalized lessons.

The ergonomic choice in this study created a paradox in the lessons. L_{FREE} resulted in a decrease in the number of times students went to hydration points, which was considered an NWA, and an increase in the number of WA. Also, the distribution in the sequences showed that the number of hydrations during L_{FREE} was significantly lower in sequence 2 than in sequence 1 (Tab2), whereas the inverse was noted for L_{REGUL} (Tab2). Thus, we observed a significant 38 % decrease in student NWA located in water hydration (personal bottle) and horseplay during L_{FREE}, and we assume that free access to water gave the students a moment of well-being (chatting and hydrating at their convenience), which had a positive impact on the NWA of horseplay. Furthermore, the ergonomic design of the workshop let them have a free stop at the water fountain and access to their personal bottle before returning to the starting zone and this too seemed to limit the horseplay. Our findings regarding NWA also indicate that, once free access to the personal bottle was authorized, the class as a whole displayed this NWA less often. We suggest that during L_{REGUL} this NWA was sometimes displayed by students as a means of disengaging

from the lesson for brief moments. In our opinion, this strengthens the idea of utilizing the classroom "artifacts" at our disposal to positive ends (Durand, 1996). Essentially, students should be allowed to have "off" moments, when they quickly drop out of the lesson without it perturbing individual work or that of the entire class. A second hypothesis is that, in the case of free hydration, when the students hydrated less (number of times they went to drink from the personal bottle), they actually hydrated better (quantity of water intake using the personal bottle) because they were responding to a specific physical need, whereas this natural response to body needs could not occur in the more coercive model where drinking was the teacher's decision. At the water point, students not only drank from their personal bottle but also splashed fountain water over their faces and scalps after drinking. Although the head represents only a very small part of the body surface, it is hypothesized that it permits substantial heat loss because of the great amount of surface blood flow in the scalp and the lack of vasoconstriction in scalp blood vessels, as opposed to surface vessels in other body areas (Froese & Burton, 1957). Very recently, head cooling has been demonstrated to attenuate the increase in core temperature during passive heating (Simmons *et al.*, 2008). As stated by Cheung (2007), "the efficacy of either face fanning or head cooling to influence either brain temperature or physiological responses and performance is not universally evident in the literature and the possible mechanisms selectively used during this phenomenon are unclear but results issued from head cooling or head fanning would tend to support the idea that afferent feedback from cooling the head, irrespective of actual brain temperature, may play an important role in regulating exercise intensity and pacing by promoting an improved subjective perception of heat stress".

This phenomenon has been demonstrated during prolonged exercise (Tatterson *et al.*, 2000 ; Hue *et al.*, 2010) with no increase in heart rate or mean skin and rectal temperature (Schlader *et al.*, 2011), as observed in the present study (Tab4). Schlader *et al.* (2011) noted that temperature changes are not required for the initiation of thermoregulatory behavior in humans and that thermal sensation and thermal discomfort are effective behavioral controllers. It is possible that, despite the very slight and non-significant change in core temperature (Tab4), the greater sensitivity to heat changes and the heightened subjective sensitivity to core temperature increases observed in children (Anderson & Mekjavic, 1996) may have impacted the workload (WA) in L_{REGUL} compared with L_{FREE}. This hypothesis is reinforced by the similar RPE scores of 10.9 ± 2.1 and 11.1 ± 1.8 for L_{REGUL} and L_{FREE}, respectively, which correspond to "rather slight effort". This method is valid for assessing the perception of effort in hot conditions (Tucker *et al.*, 2004 ; Crewe *et al.*, 2008). Indeed, cooling the head and face during exercise has been demonstrated to reverse the hyperthermia-induced increase in RPE during both passive heating (Armada-da-Silva *et al.*, 2004) and exercise (Mundel *et al.*, 2007) and the thermal strain and discomfort during passive heating without affecting the core temperature (Mundel *et al.*, 2006, 2007). The student's effort in a task depends on the perceived difficulty (Delignières, 1991) : "There is an optimal level of difficulty for every student, and our students appeared to work at acceptable levels, based on the scores and standard deviations."

4.3 The athletic performances in L_{REGUL} and L_{FREE}

Significant increases in performance are difficult to observe during transversal PE studies. As already underlinedin adult Oceanian people (Charlot *et al.*, 2015 ; Galy *et al.*, 2015), we observed some skills in the process of being acquired (technical aspects of running, quality of the impulses, the balancing role of the arms), although no significant improvements were noted for long jump and sprint performance (please see the results section). Pole vaulting, however, showed significant improvement during L_{FREE}. Anaerobic performance is known to be increased up to 5 % in the heat (Racinais & Oksa, 2010). Indeed, tropical climate increases core temperature. One can thus hypothesize that the well-being of students who are appropriately hydrated, combined with the positive impact of athletic activities on anaerobic performance in tropical climate, resulted in increased WA in L_{FREE} without significant decreases in long jump and sprint performances, while a potentially significant increase in pole vault performance was observed.

This study concerned children native to a tropical area and did not permit us to conclude that non-acclimated children would have behaved similarly, since significantly different physiological responses to heat stress were observed in acclimated and non-acclimated adults (Voltaire *et al.*, 2003).

A second point is that our objective was to reproduce the PE lessons as best we could, both maintaining the spontaneous interactions between the teacher and children and ensuring the children's compliance. We thus chose to use videos for physical activity analysis, although GPS data and measures of heart rate and rectal temperature would have been more reliable parameters for data interpretation.

5 Conclusion

To conclude, we demonstrated that students' physical activity can be significantly increased in tropical PE lessons when the ergonomic strategy of individualized hydration is applied, whereas student well-being is not affected. This strategy helps to (1) optimize physical activity and (2) reduce the consequences of thermal stress on health. We also indicate how teachers can encourage physical activity without increasing student fatigue by respecting their individual hydration needs and ensuring shade zones for recovery. However, further studies are needed to analyze the long-term effects of this ergonomic approach on the qualitiy of motor activity and/or learning in tropical PE conditions in older students and during a range of sports activities. More than 33 % of the world population lives in the humid tropics, which are characterized by consistently high monthly temperatures and rainfall that exceeds evapotranspiration for most days of the year. In addition, with the influence of global warming, it is predicted that the incidence of heat illness will also become more prevalent (Bunyavanich *et al.*, 2003). We therefore recommend that PE teachers take into consideration the moment of the day when PE lessons are programmed, especially for track activities. They can use ergonomic strategies to increase physical activity during lessons, such as providing shade zones and ventilated areas for recovery and authorizing free hydration. Children should also be informed of the importance of drinking and encouraged to drink enough water before and during exercise (around 400 ml per hour).

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