ORIGINAL ARTICLE

Effects of a swimming program on infants' heart rate response

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ABSTRACT

BACKGROUND: The physiological response has been used to characterize or estimate physical demands while exercising. The aim of this study was to analyze the infant's physiological adaptations over an intervention water program.
METHODS: Fourteen infants (36±5.08 months old) were tested before (M1) and 4 months after (M2) a well-designed swimming program aiming to develop aquatic readiness, cognitive behavior and social interaction. The physiological response was assessed based on heart rate measurements (HR, bpm) at a sampling rate of 1 Hz during several basic aquatic motor skills: 1) individual displacement in ventral position (HR@InD); 2) Individual displacement in vertical position (HR@VD); 3) immersion (HR@Im); 4) voluntary underwater displacement (HR@UnD); 5) jump from the deck (HR@JD); 6) jump from the swimming mat (HR@JM); 7) from a swimming slider (HR@Sli).
RESULTS: The HR@Im showed the lowest values (~119 bpm) at the end of the program. Main trend was for a HR decreased over time (HR@Im: -14.17±17.76%; HR@InD: -8.16±9.16%; HR@JD: -10.36±12.70%; HR@Sli: -3.48±6.40%. In all other skills, HR remained unchanged.
CONCLUSIONS: Our findings suggest that infants experience significant hear rate adaptations while participating on a swimming program. The HR decreases suggests a higher capability to perform the basic aquatic motor skills and a less stressful behavior through the lessons.

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Infant's participation in aquatic activities increased remarkably in the last few years. Simultaneously, literature reports several benefits of swimming programs on infants' development. Decreases in drowning episodes,[1] improved motor skills [2] and better social development [3] were considered main benefits after participation in swimming programs.

Currently, physiological response has been used as additional information to characterize or estimate physical demands of the basic aquatic motor skills.[4] Ethical issues can be raised when children are evaluated using physiological parameters related to metabolic or respiratory variables, which require heavy experimental apparatus for data acquisition. So, heart rate has been considered the most feasible and less invasive way to gather insight about the physiological responses at these early ages. There is consensus that heat rate might provide a good estimation the session's workload [5] and changes in conditions of acute time pressure and emotional strain or anxiety.[6]

The number of studies about infants' acute physiological response in water is scarce. Smith [7] reported significant decreases in the heart rate from 7 to 84 beats per minute during infants' immersion. Goksor *et al.*[8] verified a 25% decrease in heart rate (range: -5.0% to -50.7%) during natural diving in a group of

36 healthy infants. Martins *et al.*[9] also showed that different heart rate responses exists according to the basic aquatic motor skill performed during a swimming session (range: 114 to 152 beats per minute). Albeit this very interesting findings all research conducted selected cross-sectional designs. These acute responses may represent immediately exercise effects, but not the effect of systematic and regular exposure to water in a class conducted by a trained and qualified practitioner.

Under certain conditions, is expected that infant rapidly gets used or attenuates his behavioral response with repeated exposures to the same event or context.[10] Most of the existing evidence support physiological adaptations to stressor and exhaustive events on land during physical exercise programs. Considering that water is not regularly attended by infants, there is a need to clarify if a swimming program promotes stress reductions during the various aquatic basic motor skills. In a follow-up study of ten sessions, Michielon *et al.*[11] reported that the improvement of infant's aquatic readiness depended mainly on the advancing age and not so much from the regular environmental stimulation. However, authors used a subjective observational approach based on "keep doing" and on "free exploration" rather than physiological measures to sustain their findings. The use of heart rate monitoring through a swimming program may provide new insights about the infants' capability and the safety feeling while executing the basic aquatic motor skills.

Therefore, the aim of this study was to compare the infants' heart rate response before and after a swimming intervention program. It was hypothesized that a swimming program will be sufficient to impose heart rate decreases in most of the basic aquatic motor skills.

Materials and methods

Subjects

A group of 14 infants (36±5.08 months old) were recruited for the experiment. Included infants had no previous experience on the aquatic/swimming context with any kind of oriented program. Written parental consent for heart rate recording was obtained prior to the study. The parents were informed that they were free to withdraw their children from the study at any time, and without giving reason. Anonymity and confidentiality were assured. Infants were excluded if: 1) expressing negative reactions like crying while using the heart rate monitor; 2) not attend at least to 80% of the swimming sessions. All procedures were in accordance to the Declaration of Helsinki in respect to Human research. The local Ethics Committee approved the experimental procedures.

Swimming program

Infants were studied before (M1) and 4 months after (M2) a swimming program. Swimming sessions had a frequency of twice a week with a duration of 30 minutes each. The sessions were planned and conducted by an expert trained and qualified instructor that holds a degree in Sport Sciences & Physical Education and at least 6 years of experience teaching infant swimming. The main aim of the program was to develop infants' aquatic readiness, cognitive behavior and social interaction. Classes included the practice of several basic aquatic motor skills including ventral, dorsal and lateral displacements, immersions, gliding, balance and jumping.[12] Teaching methods were based on "individual" and/or "small groups" learning. Infants were stimulated by games to act through guided discovery and problem solving. During all sessions parents were an active resource in the water helping the instructor and giving emotional safety to infants. They received previous technical information how to manipulate their children in the water (vertical, ventral, dorsal and shoulder grips). Several forms of equipment (*i.e.* swimming mats, floating rings, colored balls, puzzles, sliding platforms) were used to make the water environment even more attractive. Pool dimensions were 16×6 m with a depth between 0.70 and 1.40 m. Water temperature and room temperature were 30.2 °C and 28.9 °C, respectively.

Data collection

All tests were conducted in the morning, during regular classes. At each testing point, infants had to perform a set of water tasks related to aquatic readiness:[12] 1) individual displacement in ventral position with a kicking board in his hands (InD); 2) Individual displacement in vertical position grabbing the deck (VD); 3) immersion (Im); 4) voluntary underwater displacement without

any support from the parent to the instructor (UnD); 5) jump from the deck (JD); 6) jump from the swimming mat (JM); (vii) swimming slider (Sli). All the displacements were set to 4 meters' distance. Immersions were made simultaneously with parents for a 3-second duration.

The heart rate (HR, bpm) was collected with a monitor (Polar S220, Finland) at a sampling frequency of 1 Hz. The coded transmitted band was adjusted around the infant's chest. The device was placed while the infants were seated on the deck. The receiver clock was placed on the parent's wrist. The parent was close to the infant for each motor skill, to avoid the loss of HR data between the transmitter and the receiver. Few weeks' earlier infants had preparatory sessions to become familiar with the HR monitor and the experimental procedures. The resting HR was also recorded (HR_{rest}=111.00±5.55 bpm). Infants only performed the aquatic skills when HR values reached individual resting HR limits. For each skill the HR was recorded and the mean value selected for further analysis. Exercise was repeated if: 1) not accomplished the distance asked, or 2) the time set for the task, or 3) data was not transmitted to the receiver, or 4) lost the bend during the various aquatic skills. No more than three repetitions were allowed to avoid any kind of task adaptation.

Statistical analysis

Kolmogorov-Smirnov and Levene tests were used to assess normality and homoscedasticity assumptions, respectively. Since, the low value of the N. (*i.e.*, N.<30) and the rejection of the null hypothesis (H_0) in the normality assessment, nonparametric procedures were selected. Data was expressed as mean and standard deviation for each testing point. Box plots and quartile data were also computed. Changes over time were analyzed with the Wilcoxon Signed-Rank Test and the relative frequency of change (%) also calculated (P≤0.05). Effect size was calculated based on eta-squared (η^2), and values interpreted as being:[13] without effect if $0<\eta^2\leq0.04$; minimum if $0.04<\eta^2\leq0.25$; moderate if $0.25<\eta^2\leq0.64$ and; strong if $\eta^2>0.64$. Data were reported to have a "meaningful variation" if significant (P≤0.05) with a moderate or strong effect size ($\eta^2>0.25$), and a "significant variation" if significant (P≤0.05) with a small effect size ($\eta^2\leq0.25$).[14]

Results

Figure 1 presents the variations in HR over the swimming program. A meaningful variation was found in the HR@Im ($HR@Im_{M1}$=134.86±11.74, $HR@Im_{M2}$=119.57±12.84, P=0.01; η^2=0.33). Significant variations were verified in the HR@InD ($HR@InD_{M1}$=141.43±12.62, $HR@InD_{M2}$=131.14±11.02, P=0.01, η^2=0.17), HR@JD ($HR@JD_{M1}$=133.14±13.20, $HR@JD_{M2}$=121.14±8.72, P=0.02, η^2=0.25) and HR@Sli ($HR@Sli_{M1}$=137.29±11.17, $HR@Sli_{M2}$=132.79±8.67, P=0.05, η^2=0.05). The HR@VD ($HR@VD_{M1}$=142.86±9.36, $HR@VD_{M2}$=138.07±12.96, P=0.12), HR@UnD ($HR@UnD_{M1}$=132.14±10.59, $HR@UnD_{M2}$=134.64±10.07, P=0.21) and HR@JF ($HR@JM_{M1}$=138.86±12.28, $HR@JM_{M2}$=135.64±7.90, P=0.14) presented unchanged HR values though. The HR@Im was the measure that presented the lowest values (~119 bpm) after the program. Remaining water skills presented HR values ranging from ~130 to ~140 bpm.

Table I presents the relative changes (expressed as percentage) in the HR between over time. The highest change happened in the HR@Im (-14.17±17.76%). Interestingly, the HR@UnD was the only variable that increased over time (1.10±13.78%).

Discussion

The aim of this study was to analyze the HR changes of infants attending a swimming program. At the end there were significant HR decreases in several aquatic skills, such as, individual displacements, immersions, jumping from de deck or sliding from the platform. This represents a less physical demand and a less stressful behavior while performing those basic aquatic motor skills due to regular exposure to swimming sessions.

This study was the first to assess infants' physiological response with a longitudinal research, assessing the changes of HR over time. So, this is a step further on infant's swimming research because as much as we understand not one single paper provides this kind of insight. Previous studies on infants had a cross-sectional approach and were conducted on a more controlled environment with the presence of unknown subjects for infants inside the water and on the pool deck.[7] However, more recent approaches have been trying to get experimental data in a more real practice environment.[9] With this intervention we aimed to get physiological data in
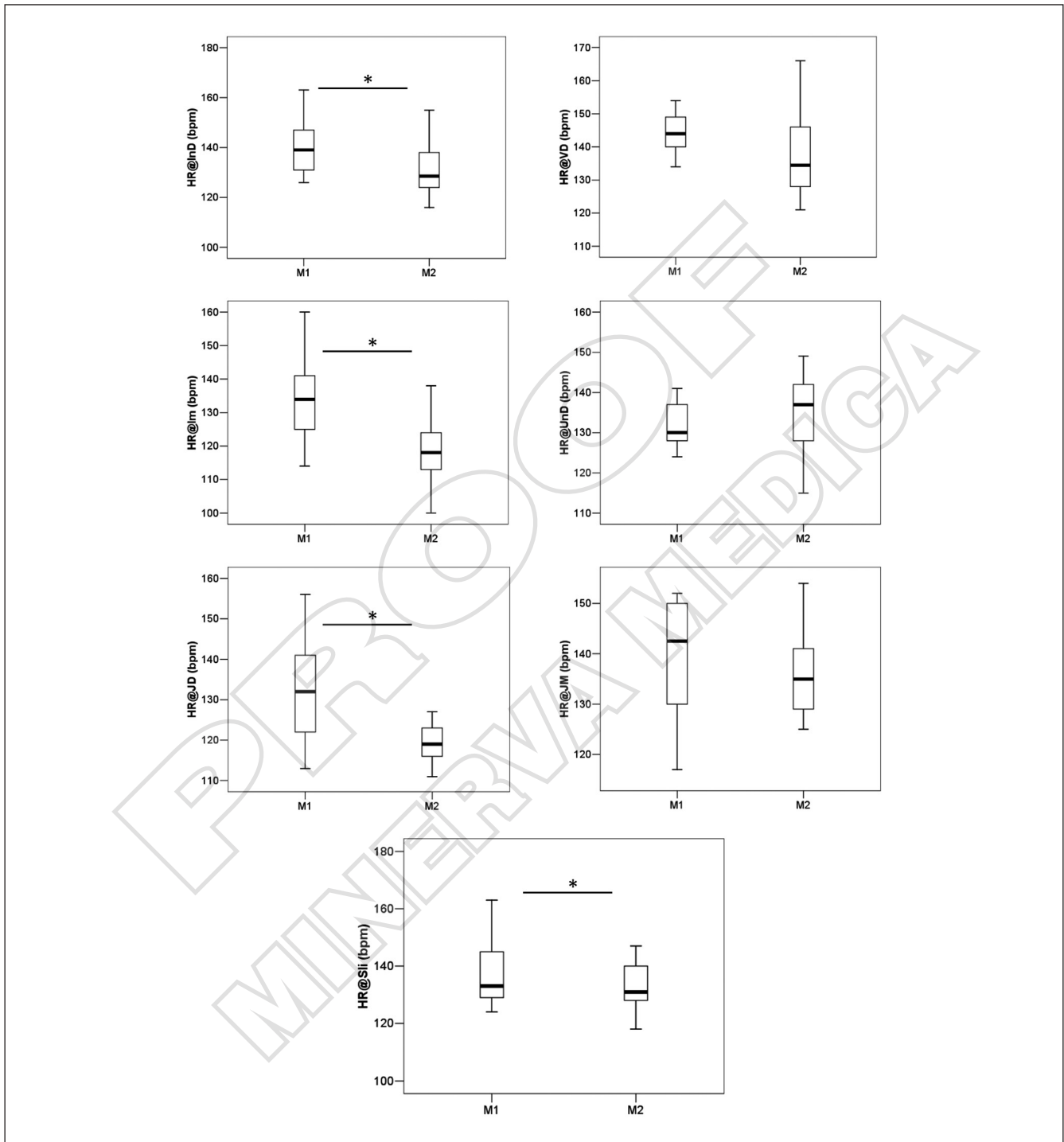
Figure 1.—Variations in mean HR data over the swimming program. *Significant variations between M1 and M2 (P<0.05).
HR@InD: heart rate during individual displacement; HR@VD: heart rate during vertical displacement; HR@Im: heart rate during immersion; HR@UnD: heart rate during underwater displacement; HR@JD: heart rate during jump from the deck; HR@JM: heart rate during jump from the matt; HR@Sli: heart rate during slide from the platform.

TABLE I.—*Relative changes in heart rate (HR) according to the aquatic skills.*

HR during aquatic skill	Relative change (%)
HR@InD	-8.16±9.16
HR@VD	-3.90±7.36
HR@Im	-14.17±17.76
HR@UnD	1.10±13.78
HR@JD	-10.36±12.70
HR@JM	-2.44±7.90
HR@Sli	-3.48±6.40

HR@InD: heart rate during individual displacement; HR@VD: heart rate during vertical displacement; HR@Im: heart rate during immersion; HR@UnD: heart rate during underwater displacement; HR@JD: heart rate during jump from the deck; HR@JF: heart rate during jump from the matt; HR@Sli: heart rate during slide from the platform.

a traditional infants' class that is often set in the most of the swimming facilities.

We selected HR as the variable to understand infants' physiological changes over time. From an experimental perspective, other physiological parameters related to metabolic or respiratory variables (such as oxygen uptake or blood lactate concentrations) and stress behavior (such as salivary cortisol) can be selected. However, ethical concerns are raised if used on infants. Thus, HR is the only and more feasible way to gather insight about physiological changes over time in such early ages. Indeed, the existing literature deals primarily with HR to understand infants' physiological behavior in both water and land environments.[8, 9, 15, 16] The HR values recorded in this study (~133 bpm) are in accordance with previous cross-sectional evidences.[8, 9] Literature suggests that mean HR values around 120 bpm are enough to have a vigorous physical demand at these ages.[17] Based on our HR data, one might consider that the program carried out seem to be suitable to elicit the desired physical effort.

There were meaningful deceases in HR@Im with the highest relative change (-14.17%) over time. Although immersions can be considered aquatic skills involving some fear at the first time experience, there are reports that HR reductions can be found due to proper acquisition of the bradycardia reflex.[18] Significant decreases were also observed for more demanding skills such as HR@InD, HR@JD and HR@Sli. At submaximal levels of exercise, cardiac output is unchanged or slightly decreased in young children after endurance exercise sessions, as a result of an increased submaximal stroke volume and a decreased HR.[19] As the cardiac muscle of infants will grow stronger over time, the heart becomes adapted and similar exercises are no longer so exhaus-

tive. So, the HR changes can express the individual capacity to fulfil physical challenges. Probably, the HR decreases suggest that infants were more capable to perform the aquatic basic skills in a higher number of repetitions than in previous sessions and increase energy spent through the program.

It is also possible that regular exposure to swimming sessions may leaded to a reduction in fear while performing the aquatic skills. From some psychophysiological reports, the HR may change based on emotional status and under stressful conditions.[6] When experiencing stress, the body goes through a series of physiological responses that feed into both nervous and circulatory system and affect from hormones to heart rate. This response of the body during times of stress is well-documented and floods the body with hormones that increase HR. However, the opposite phenomenon happened during the intervention program. There are evidences that infants get used or attenuate its stressful response with repeated exposures to the same event or context.[10] Hertsgaard *et al.*[20] verified that the reactions of infants who took part in only two sessions of swimming class showed less negative and more positive emotional behavior. So, one expects a stronger engagement and a less stressful behavior over a swimming program.

The HR@VD, HR@UnD and HR@JM remained unchanged over the program. Some evidence suggests that HR is a measure that can be used to assess the autonomous nervous system modulation under physiological condition depending on different body positions.[21] Both vertical displacement grabbing the deck and underwater displacement are skills where infants do not have a visual contact with their parents. Probably, those are aquatic skills where it settles a less safety feeling and a long

time period is necessary to express significant physiological adaptations. Surprisingly, HR@UnD was the only measure that increased over time (1.10±13.78%). However, with a closer inspection, the HR@UnD decreased in four infants and two other showed unchanged values. This might suggest that this can be one of the skill with the largest variability in HR response, mainly from the transition from vertical to ventral positioning with underwater displacement.

The HR@Im was the skill that presented the lowest values (~119 bpm) after the program. There is consistent evidence that HR decreases during immersions. Immediately upon facial contact with water, the human HR slows down 10-25%.[22] Although this response diminishes with increasing age, there are reports that bradycardia reflex is still obvious in infants over 6 months.[8] Indeed, this phenomenon is maintained through adolescence, adulthood and elderly. Added to that, immersion is a skill that is mostly promoted by parents, with a passive participation by the child. Since infants are being grabbed by their parents, vigorous movements are not expected, reducing the physiological demands for that specific task. Our findings differ from those reported by Martins *et al.*[9] but are in agreement with interventions comparing on land *versus* aquatic behaviors.[23] Differences between researches can be explained by the sample characteristics. Martins *et al.*[9] justified the higher HR@Im upon infants that were engaging in immersions for the first time, presenting fear in the first trial. Hence, it is fair to suggest that this was a class with a very heterogeneous level, in contrast with the one from the present study. The remaining aquatic skills presented higher HR values (ranging from ~130 to ~140 bpm) than the HR@Im. Those are skills requiring active participation by the infant with autonomous control, *i.e.* propelling himself. The muscle contractions to stay in the upright position, the movement of the upper limbs to grab the deck and the impulsions with lower limbs to jump to the water can help explain the higher HR values.

Some limitations can be reported: 1) the reduced sample size (and therefore the statistical power); 2) there is no mid-test that would help us to have a better understand of the HR variation over time; 3) additional physiological variables (*e.g.* hormonal profile, such as salivary cortisol) could give a deeper insight, but it can raise ethical concerns.

Conclusions

Our findings suggest that infants demonstrate significant HR changes while participating on a swimming program. The HR decreases indicate that infants are more capable to perform the basic aquatic motor skills. In addition, HR decreases in some skills suggests a less stressful behavior through the lessons. One can consider that a well-designed swimming program conducted by an expert instructor can promote the desirable effects in aquatic readiness, cognitive behavior and social interaction of infants.

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