ORIGINAL ARTICLE

Performance, rating of perceived exertion and physiological responses during a Brazilian jiu-jitsu match: comparisons between winning and losing athletes

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Abstract

The purpose of the present study was to describe the physiological, perceptive and performance responses across Brazilian jiu-jitsu (BJJ) match simulation and compare them between winning and losing athletes. Fourteen male adult BJJ athletes (age: 25.8 ± 3.4 years; height: 174.8 ± 9.2 cm; body mass: 79.6 ± 12.4 kg; training experience: 7.0 ± 2.5 years), 6 brown and 8 black belts participated in this study. All athletes performed a combat simulation of 10 min. Heart rate (HR), rating of perceived exertion (RPE) and maximal isometric handgrip strength (MIHS) were evaluated before the combat and during the combat after the 2nd, 4th, 6th, 8th, and 10th minutes, while blood lactate ([La]) was measured before and after the combat simulation. Results indicated that, irrespective of the match outcome (i.e. winner or loser), significantly higher ($P < 0.05$, partial $\eta^2 = 0.346$–0.922, large) values of [La], HR, RPE, and MIHS were observed after the combat simulation when compared to before the combat. However, no significant differences between the winner and loser athletes were found ($P > 0.05$). These results suggest that the effort performed and the physiological and perceptual responses are similar among BJJ athletes competing against each other.

Keywords Grappling · Combat sports · Intermittent exercise · Physiology

Introduction

Brazilian jiu-jitsu (BJJ) is a grappling combat sport practiced worldwide, which has as a fundamental principle the use of the opponent's force against himself/herself, also known as "ju" or softness. The main goal during official BJJ matches is to control the opponent aiming at a submission through the application of strangle, pressure, or joint lock techniques (International Brazilian Jiu-Jitsu Federation, 2018). Although official matches start in the standing position, most of the combat is developed on the ground, and the typical effort–pause ratio is 6:1 during official matches [1] to 7:1 in simulated matches [2]. The typical sequence is composed of 117 s of effort and 20 s of pause [1] to 214 ± 84 s of effort and 69 ± 40 s of pause in 10-min simulated matches [2]. During the combat phase, BJJ athletes perform different actions varying in intensity and duration. In a 10-min simulated match, BJJ athletes typically engage in 16 ± 3 high-intensity actions lasting a total of 47 ± 8 s, interspersed by 17 ± 2 low-intensity actions lasting a total of 553 ± 8 s. Consequently, a high-intensity to low-intensity effort ratio of 1:11 was observed in BJJ matches [3]. Thus, this ratio seems to provide enough time for recovery and may allow the BJJ athletes to perform high-intensity actions up to the end of the match.

Physiological measurements (e.g. oxygen uptake (VO_2), blood lactate concentration, [La]; heart rate, HR) during BJJ official matches are difficult to conduct due to the close contact between the athletes [4]. Thus, several studies have measured physiological responses before and after single [5,

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6]—including matches with different durations [7, 8]—and multiple simulated or official BJJ matches [9–12]. These studies allowed a partial characterization of the physiological responses in different phases of the matches and of the competition. Moreover, these studies assessed physiological (e.g. [La], HR), rating of perceived exertion (RPE) and performance (e.g. maximal isometric handgrip strength (MIHS), strength endurance and muscle power) responses to these different conditions. [La] has been used to indicate the glycolytic activation during the match and HR as an indicator of the cardiovascular solicitation caused by the match, whereas RPE has been considered an indication of the overall exertion perceived by the athlete [9, 10]. Additionally, handgrip maximal strength and strength endurance constituted the most assessed performance variables because the execution of BJJ techniques demands the grip on the opponent's uniform (gi) [8]. Thus, an understanding of variations in these variables can provide relevant information about the physical demand of the BJJ matches.

In addition, Olympic-level judo athletes presented lower [La] in response to a simulated judo match compared to non-elite judo athletes [13] and Olympic-level judo athletes presented lower HR values during uchi-komi (technique repetition), nage-komi (technique repetition throwing the partner) and match simulation compared to national-level ones [14]. These studies suggest that higher-level athletes may have lower physiological responses compared to lower-level ones when performing a given task. However, no study measured the physiological, perceptive and performance responses in different times of a single match and compared these responses between the winner and loser BJJ athletes. Thus, the main objective of the present study was to describe the physiological, perceptive and performance responses across one BJJ match simulation and compare them between the winner and loser athletes. Given that BJJ is a very technical combat sport and the principle of "ju" associated with its practice, we hypothesized that winners would present a lower physiological, perceptive and performance decrement along the match compared to loser BJJ athletes.

Materials and methods

Study design

BJJ athletes (brown and black belts) who were training more than four times per week (90–120 min per session), for longer than 4 years, and free from injury were recruited to take part in the present study. They performed a single 10-min BJJ simulated match against an opponent of the same weight category, grade, and experience. Athletes from different BJJ clubs were matched to increase competitiveness. Physiological (HR), perceptive (RPE), and

performance (MIHS) responses were measured before and during the match (at second, fourth, sixth, eight, and tenth minutes), whereas [La] response was measured immediately before, 1, and 3 min after the match. The match was finished only by time, and if a submission occurred they were instructed to restart in the standing position. The BJJ athlete with higher scores was considered the winner. An experienced BJJ referee officiated all the matches. The BJJ athletes were instructed to prepare for the match simulation as they typically prepared for a competition. Briefly, they were instructed to avoid high-intensity physical efforts 24 h before the match simulation, to avoid alcohol and caffeine intake, to have their regular competition breakfast. The only change compared to a regular competition was the recommendation to the BJJ athletes to not engage in any weight loss procedure 1 week before the simulation. Matches were conducted during the morning, in an official competition area. All matches were performed on the same day, at a temperature of 24 °C and 53% of humidity. All BJJ athletes were in their competitive period and instructed to behave as in an official competition.

Participants

Fourteen male adult BJJ athletes (mean and standard deviation; age: 25.8 ± 3.4 years; height: 174.8 ± 9.2 cm; body mass: 79.6 ± 12.4 kg; training experience: 7.0 ± 2.5 years) took part in the present study. They were ranked as brown ($n = 6$) and black belt ($n = 8$), had more than 4 years of BJJ training experience, and were competing stately and nationally. Exclusion criteria comprised athletes using rapid weight loss procedures, taking supplements, or injured. This study was approved by the local ethics committee (process 2011/32) and all participants gave their written informed consent prior to the start of the study.

Body mass and height measurements

Body mass was measured in a calibrated Filizola scale (Sao Paulo, Brazil), with 0.1 kg precision, and height was measured using a portable stadiometer (Seca 222, New York, USA), with 1 mm precision, in accordance with Heyward [15].

Match simulation

The match simulation was 10-min long and was not finished in case of a finalization technique to guarantee that all BJJ athletes would be exposed to the same match duration, a procedure used in other studies [10, 11]. Athletes were paired based on their grade, weight category, and technical level. Before the match, athletes conducted their usual warm-up for 10 min and a 5-min interval was used between the end of

the warm-up and the beginning of the match simulation. An experienced referee officiated all matches. The outcome (i.e. determination of winner and loser athletes) of each match was recorded based on the total score of each athlete. A 30-s interruption was inserted at 2nd, 4th, 6th, and 8th minutes to allow the HR, RPE, and MIHS measurements. HR, RPE, and MIHS were also measured at the 10th minute, using the same 30-s period, whereas [La] was measured before, 1 and 3 min after the match.

Maximal handgrip strength measurements

Before the match, the MIHS was measured three times on the dominant hand, with a 1-min interval between attempts, and, in each one, the athlete was instructed to generate the greatest possible force during 3–5 s, in a standing position, with fully extended elbow and self-selected wrist positions. However, the hand or arm could not touch the body during the test execution. Measurements were conducted using a Jamar dynamometer (model J00105, Lafayette, LA, USA), with a 1 kgf precision. The highest value was used for this moment. Additionally, a single attempt was conducted at the 2nd, 4th, 6th, 8th, and 10th minutes. For values measured during the match percentage values in relation to the maximal value were calculated. The dynamometer were set according to each athlete's hand length, following the recommendations of the American Society of Hand Therapy [16]. A previous study from our laboratory [9] demonstrated that this test was reliable (intraclass coefficient correlation = 0.72, $P < 0.05$) when BJJ athletes were tested under similar conditions as used in the present study.

Heart rate measurements

HR measurements (Polar Pace, Polar, Kempele, Finland) were conducted at the 2nd, 4th, 6th, 8th, and 10th minutes, before the MIHS measurements to avoid that interfering with the HR results.

Blood lactate measurements

Blood samples were collected at the earlobe to determine [La] using the Accutrend equipment (Roche Diagnostics, Mannheim, Germany), before, 1, and 3 min after the match simulation. The highest value was considered the peak [La].

Statistical analyses

Statistical analyses were performed using a Statistica for Windows software (Statisoft, version 8, Tulsa, USA). Data are presented as mean and standard deviation. An independent Student's t test was used to compare age, body mass, height, BJJ experience, and MIHS of winning and losing

BJJ athletes. A two-way (match outcome and time of measurement) with repeated measurements in the second factor was used to compare [La], HR, RPE and MIHS along the match simulation. A Mauchly test was used to confirm the assumption of sphericity of the data and no correction was needed for these variables. Cohen's d was calculated for comparisons between groups for age, body mass, height, BJJ experience, and MIHS, and classified according to Hopkins et al. [17], with values of ≤ 0.2, > 0.2 and < 0.6, > 0.6 and < 1.2, > 1.2 and < 2.0, and ≥ 2.0 considered as trivial, small, medium, large, and very large effects, respectively. Partial eta squared (partial η^2) was used as effect size for multiple comparisons, and classified according to Cohen [18], with the 0.0099, 0.0588, and 0.1379 effect sizes considered as small, medium, and large, respectively. The significance level was set at 5%.

Results

Table 1 presents the main characteristics of BJJ athletes from the winning and losing groups.

Winner and loser groups did not differ concerning age ($t_{12} = -1.19$, $P = 0.257$, $d = -0.63$, medium), body mass ($t_{12} = -0.04$, $P = 0.969$, $d = -0.002$, trivial), height ($t_{12} = 0.74$, $P = 0.473$, $d = 0.40$, small), BJJ experience ($t_{12} = -1.25$, $P = 0.233$, $d = -0.66$, medium), and MIHS ($t_{12} = 1.77$, $P = 0.103$, $d = 0.87$, medium).

Figure 1 presents the maximal handgrip strength response along the match simulation for the winner and loser groups.

There were no main effect of match outcome on absolute ($F_{1,12} = 1.97$, $P = 0.186$, partial $\eta^2 = 0.141$, large) or relative MIHS ($F_{1,12} = 0.22$, $P = 0.651$, partial $\eta^2 = 0.018$, small). However, a main effect of time was found for both absolute ($F_{4,48} = 8.19$, $P < 0.001$, partial $\eta^2 = 0.406$, large) and relative ($F_{4,48} = 7.76$, $P < 0.001$, partial $\eta^2 = 0.393$, large) MIHS, with higher values in the 2nd minute compared to the 6th, 8th, and 10th minutes ($P < 0.001$ for all comparisons for both absolute and relative values), and higher values in the 4th compared to the 10th minute ($P < 0.05$ for

Table 1 Age, body mass, height, Brazilian jiu-jitsu (BJJ) experience, and maximal isometric strength in winning and losing BJJ athletes in a match simulation

	Winners ($n = 7$)	Losers ($n = 7$)
Age (years)	24.7 ± 2.8	26.9 ± 3.9
Body mass (kg)	79.5 ± 14.7	79.8 ± 10.9
Height (cm)	176.6 ± 11.1	172.9 ± 7.2
BJJ experience (years)	6.2 ± 1.9	7.9 ± 2.9
Maximal isometric handgrip strength (kgf)	63 ± 9	54 ± 10

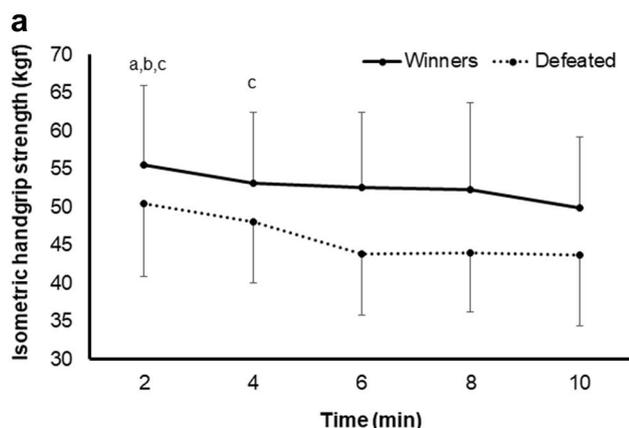Values are mean and standard deviation

Fig. 1 Absolute (**A**) and relative (**B**) maximal isometric strength along a Brazilian jiu-jitsu (BJJ) match simulation in winning and losing BJJ athletes. Values are mean and standard deviation; a = main effect of moment of measurement, different from the 6th min ($P < 0.05$), b = main effect of moment of measurement, different from the 8th min ($P < 0.05$); c = main effect of moment of measurement, different from the 10th min ($P < 0.05$)

both absolute and relative comparisons) of match simulation. Moreover, no significant interactions were observed for absolute ($F_{4,48} = 0.99$, $P = 0.419$, partial $\eta^2 = 0.077$, medium) or relative MIHS ($F_{4,48} = 1.05$, $P = 0.394$, partial $\eta^2 = 0.080$, medium).

There was no main effect of outcome ($F_{1,12} = 1.33$, $P = 0.272$, partial $\eta^2 = 0.099$, medium). However, [La] was affected only by time ($F_{1,12} = 142.62$, $P < 0.001$, partial $\eta^2 = 0.922$, large), with peak post-match values (8.79 ± 2.34 mmol L^{-1}) being higher ($P < 0.001$) than values pre-match (2.19 ± 0.55 mmol L^{-1}). Moreover, no significant interaction was observed for [La] ($F_{1,12} = 4.54$, $P = 0.055$, partial $\eta^2 = 0.274$, large).

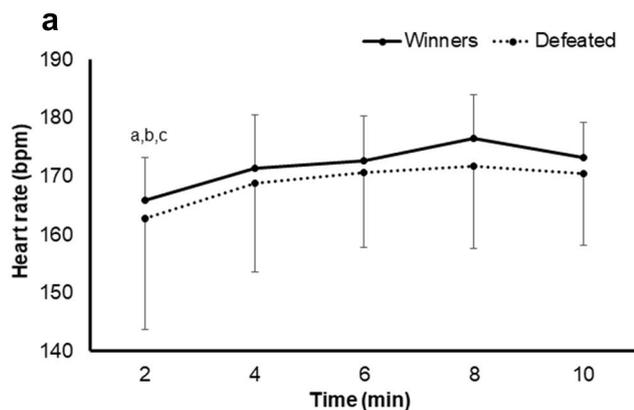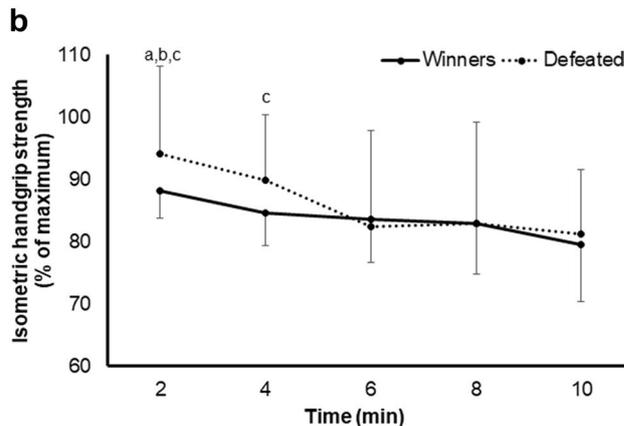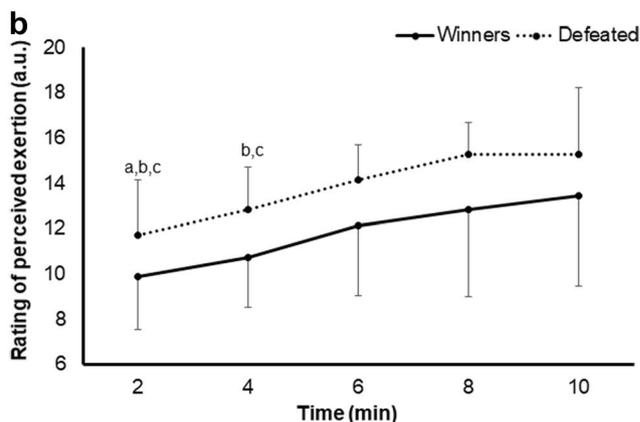Figure 2 presents HR and RPE responses during the match simulation for winner and loser BJJ athletes.

There was no main effect of outcome ($F_{1,12} = 0.28$, $P = 0.608$, partial $\eta^2 = 0.023$, small). However, HR was affected by time ($F_{4,48} = 6.36$, $P < 0.001$, partial $\eta^2 = 0.346$, large), with lower values in the 2nd minute compared to the 6th, 8th, and 10th minutes ($P < 0.01$ for all comparisons) of the match simulation. Furthermore, no significant interaction was observed for HR ($F_{4,48} = 0.12$, $P = 0.975$, partial $\eta^2 = 0.010$, small).

There was no main effect of outcome for RPE ($F_{1,12} = 2.59$, $P = 0.133$, partial $\eta^2 = 0.178$, large). However, RPE was also only affected by time ($F_{4,48} = 16.34$, $P < 0.001$, partial $\eta^2 = 0.577$, large), with lower values in the 2nd minute compared to the 6th, 8th, and 10th minutes ($P < 0.001$ for all comparisons) and lower values in the 4th compared to the 8th, and 10th minutes ($P < 0.001$ for both comparisons)

Fig. 2 Heart rate (**A**) and rating of perceived exertion (**B**) during Brazilian jiu-jitsu (BJJ) in winning and losing BJJ athletes. Values are mean and standard deviation; a = main effect of moment of measurement, different from the 6th min ($P < 0.05$), b = main effect of moment of measurement, different from 8th min ($P < 0.05$); c = main effect of moment of measurement, different from the 10th min ($P < 0.05$)

of the match simulation. Moreover, no significant interaction was observed for RPE ($F_{4,48} = 0.10$, $P = 0.982$, partial $\eta^2 = 0.008$, small).

Discussion

The main hypothesis of the present study that winners would present a lower physiological, perceptive, and performance decrement along the match compared to loser BJJ athletes was not confirmed, as no significant difference was observed between winner and loser BJJ athletes in any of the measurements conducted in the present study (i.e. MIHS, [La], HR and RPE). However, a decrease in MIHS was observed along the match, as well as increases in [La], HR, and RPE.

MIHS is considered a relevant physical component for BJJ athletes [1, 7–9]. In our study, maximal handgrip strength at the 10th minute was approximately 20% lower compared to maximal values obtained pre-match, indicating that the match resulted in an important decrease in this variable, although no difference was observed between the winner and loser BJJ athletes. Former investigations on the effect of BJJ match on MIHS indicated 13% and 16% decreases in the right and left handgrip strength after official regional BJJ matches lasting approximately 5 min [1], 10% decrease in the dominant hand after an official regional match [6], and approximately 9% decreases in the dominant and non-dominant hands after the first of four 10-min BJJ simulated matches [9]. Thus, the decrease in the present study was more accentuated than that previously reported in the literature. The difference in strength decrease magnitude between the current study and the previous studies [1, 6, 9] seems to be due to a higher match intensity. Another possible explanation for this difference can be the subsequent measurements conducted along the match in our study, i.e. the repetition of maximum attempts summed to the match demand may have resulted in an additional decrease in maximal strength. Indeed, all other investigations analysed simply pre- versus post-match values. Only Andreato et al. [8] included shorter match durations, which were conducted using long intervals between them and avoided the potential negative influence of subsequent maximal strength test repetitions. We only found one study [8] that analysed the MIHS decrement in 2-min, 5-min, 8-min, and 10-min simulated BJJ matches, but these authors reported no change when durations were compared. Thus, this emphasizes that the use of the maximal strength tests along the match may have contributed to the higher decrease observed in our study. Therefore, this can be considered a limitation of the present study.

[La] measurements before and after BJJ matches were conducted in several studies [1, 5–7, 10] and all reported increases after the matches, with post-match values varying from 6.2 ± 2.3 to 11.9 ± 5.8 mmol L^{-1} when matches

longer than 5 min were performed. Thus, our simulation resulted in a similar glycolytic activation as reported in the literature. However, it is important to emphasize that in our study no difference was found between the winner and loser BJJ athletes. This differs from the observation that elite judo athletes finished their match with lower [La] compared to non-elite judo athletes [19]. Nevertheless, that study with judo athletes [19] did not pair the opponents considering athletes' competitive level (i.e. matches were disputed by elite versus elite, elite versus non-elite, and non-elite versus non-elite judo athletes), whilst in the present investigation we compared winner and loser BJJ athletes who contested the same match. Additionally, Da Silva et. [20] did not find any difference in [La] between advanced and non-advanced BJJ athletes playing three consecutive matches (each group disputed against athletes from the same level). Thus, the glycolytic activation does not seem to vary between BJJ athletes contesting the same match. However, future studies could explore the [La] responses in BJJ athletes from different competitive levels contesting between them to verify if more advanced or elite BJJ athletes would present a lower glycolytic activation when playing a match against lower level BJJ athletes.

HR has been used as a measurement to infer the cardiovascular solicitation of BJJ matches [5, 7, 10], all reporting increases from pre-match to post-match, and values achieving 165 ± 17 bpm to 169 ± 6 bpm, which is slightly lower compared to the values achieved in the 10th minute of our combat simulation. Andreato et al. [7] reported values after 2-min (159 ± 12 bpm), 5-min (159 ± 11 bpm), 8-min (166 ± 98 bpm) and 10-min (167 ± 15 bpm) matches, but contrary to our findings, they did not find any difference between the different durations. Conversely, our data suggest that the first 2 min resulted in lower cardiovascular solicitation compared to the 6th minute up to the end of the match. This HR response seems to be related to the typical transition from rest to exercise [21]. The small increase after the 4th minute was probably due to the controlled effort conducted by the BJJ athletes, who normally use the beginning of the matches to obtain information about their opponents and, thus, avoid high-intensity efforts, unless an opportunity to end the match is presented [7].

RPE was also lower at the 2nd minute compared to the 6th, 8th, and 10th minutes, confirming the strategy of effort control at the beginning of the combat. This response can be related to the fact that RPE response is also affected by time [22], and even if the BJJ athletes were performing at the same intensity along the match, their RPE would be lower at the first few minutes of the match. Indeed, Andreato et al. [8] found that BJJ reported higher RPE values at 8-min (14 ± 2 a.u.) and 10-min (15 ± 2 a.u.) matches compared to 2-min matches (12 ± 2 a.u.), which is quite similar to that observed in our study. Another important finding was

that BJJ achieved mean values around 14 at the end of the match, suggesting that they set a comfortable exertion to avoid extreme fatigue negatively affecting their decision-making. Andreato et al. [9] reported that, during a competition simulation, as BJJ athletes became more fatigued, their defensive actions were less effective. Thus, it is likely that experienced BJJ athletes, as those who took part in the present study, would avoid high-intensity effort unless a clear opportunity to score is noted. Investigations that registered RPE responses to BJJ matches reported values around 12 (i.e. "light") in simulations [5], 16 (i.e. hard) in simulated competition [9], and 15 [1] and 16 (i.e. "hard" for both) during regional tournaments [6]. Therefore, the value observed in the present study was very close to that reported in regional competitions. Bridge et al. [23], when analyzing RPE responses to international taekwondo competition, suggested that a possible explanation for the submaximal RPE during combat can be related to the decision-making process during the physical effort, which could decrease the sensation of effort. Accordingly, Andreato et al. [9] reported that in grappling combat sports, there is substantial visual, proprioceptive and kinesthetic data processing, factors that could contribute to a lower RPE.

The main limitation of our study was the need to stop the match to conduct the measurements. It is important to consider that the match was stopped only every 2 min and by a period similar to the pauses normally called by the referee. However, the execution of the maximal strength tests along the match may have contributed to a higher decrease in MIHS observed in our study.

In conclusion, regardless of the combat outcome, MIHS decreased along the BJJ match, whilst [La], HR, and RPE increased. When considering winner and loser BJJ athletes apart, no significant differences were observed in all the undertaken measures. This suggests that the effort performed and the physiological responses are similar among BJJ athletes competing against each other.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval This study was conducted in accordance with the the 1964 Declaration of Helsinki and its 2013 amendment.

Informed consent All participants gave their written informed consent prior to the beginning of the study.

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