# Physiological and perceptual responses for specific *taolu* exercises (empty-hand versus heavy bag performance)

**Authors' Contribution:**
**A** Study Design
**B** Data Collection
**C** Statistical Analysis
**D** Manuscript Preparation
**E** Funds Collection

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**Received:** 27 February 2018; **Accepted:** 05 September 2018; **Published online:** 14 November 2018

**AoBID:** 12003

## Abstract

**Background and Study Aim:** *Taolu* or kung-fu forms are established sequences of offensive and defensive techniques representing fights against fictitious opponents that require motor control, rhythm, and movement differentiation capacities. In mostly styles, forms can be performed empty-hand or using a heavy bag or wooden-dummy. However, differences on acute physiological and perceptual responses when *taolu* are performed in both ways have not been studied so far and remain unknown. Therefore, the aim of this study was knowledge about acute heart rate (HR) and blood lactate [$La^-$] responses, and the rated perceived exertion (RPE) on the performance of empty-hand versus heavy bag *taolu* in amateur practitioners.

**Material and Methods:** Twelve male kung-fu practitioners participated in this study. HR, [$La^-$] and RPE were measured before, during and after different study conditions. Tests were performed in a randomized order on heavy bag or empty-hand, in two sessions. HR was measured through a cardio-tachometer, [$La^-$] using a Lactate Analyser and RPE through the Borg's Scale. Statistical analysis was made using a two-way ANOVA with repeated measures.

**Results:** No significant differences were found between two analysed conditions in $HRW_{mean}$, p = 0.659; $HRW_{max}$, p = 0.574; $\%HRW_{mean}$, p = 0.605; $\%HR_{max}$, p = 0.742. Also, no significant differences were found in [$La^-$] responses, both $[La]_{post}$ (p=0.658) and $[La]_{3'}$ (p = 0.436), between the two analysed forms. Regarding RPE, no significant differences (p = 0.068) were found between study conditions. The performance of *taolu* hitting a heavy bag does not represent a higher cardio-metabolic stress, nor higher subjective perceived strain for kung-fu athletes, compared to the performance of empty-hand *taolu*.

**Conclusions:** The practical applications of these findings are the different possibilities of training that presents the performance of *taolu*, with or without using heavy bag indistinctly, since the results when performing empty-hand and bag *taolu* are similar, in terms of physiological and perceptual effects. Thus, martial arts' athletes who cannot hit the heavy bag, either because of an injury or because it is not easily available, can perform only empty-hand forms, obtaining the same physiological benefits.

**Keywords:** acute effects • blood lactate concentration • heart rate • kung-fu •rating perceived exertion



**Conflict of interest:** Authors have declared that no competing interest exists

**Ethical approval:** The study project was approved by the Ethics Committee of the University of Alicante Ethics Committee (UA-201 6-09-17)

**Provenance & peer review:** Not commissioned; externally peer reviewed

**Source of support:** The study supported from a pre-doctoral grant ACIF/2016/048 from the Generalitat Valenciana (Spain)

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## INTRODUCTION

Chinese martial arts were anciently developed with the focus on waging wars. In a modern context, it has evolved to systems of hand-to-hand fighting and self-defence systems [1]. At present, there are different and varied styles that not only have led to competitive sport but also, they have been used as a training method aimed to the improvement of health and fitness [1, 2, 3]. In fact, most studies evaluating martial arts have found positive effects on health, such as increased cognition, muscle strength, flexibility, and balance [3, 4, 5]. In recent years, traditional martial arts' styles have also become quite important as popular combat sports, with a positive trend in its use as training methods worldwide, prompting researchers to investigate the physiological factors that improve their performance and prevent injuries [6-8].

Kung-fu is one of these Chinese martial arts that has existed for centuries and is generally accepted as being beneficial for health [3]. Throughout its historical development as martial art, kung-fu movements have been refined and expanded, becoming advantageous not only for fitness but self-defence as well [9]. The practice of kung-fu involves the performance of moderate-to-high-intensity forms of exercise that encompasses multiple aspects of conditioning [3, 10]. This practice might confer training benefits, similar to those attributed to other combat sports modalities, and might prevent many of the negative effects of aging [7, 11-13]. Nonetheless, there is a scarce research to date in kung-fu dealing with these issues [14] and it seems that there is no robust research to support the different issues regarding health and performance benefits that can be obtained by practicing this martial art [3].

Within the kung-fu we can distinguish hundreds of styles, but all they can be classified into two disciplines: traditional and formalised (*taolu*, also called forms) and modern combat (*sanshou*, also called *sanda*) [15]. In *taolu* discipline, a set of choreographed movements, can be performed empty-hand, with weapons, against other practitioners, against wooden dolls or using heavy bags. Otherwise, *sanshou* or *sanda* discipline is characterized by regulated one-on-one sparring [16]. In *taolu* or forms discipline, practitioners make predetermined sets of techniques in a known sequence against opponents, whether imaginary or not, whose movement is performed in various directions in the space [8, 17]. The improvement of technique, rhythm, power, expressiveness of movements, etc., are the main objectives of training these *taolu* [18]. In order to make a correct form, a series of skills like motor control, rhythm and differentiation of movements are required, and they must be combined with dynamic and explosive movements which elicits high physiological responses in the organism [10, 17, 18, 19].

To ensure the desired effects of wellbeing and high performance, martial arts' athletes should be closely monitored in their training [18]. Training monitoring is usually developed using physiological, biochemical, performance, and perceptual measures [19]. Currently, there is a relatively poor understanding of which measures are most appropriate for training monitoring in sports [20]. Intra-assay and inter-assay variability, intra-individual and inter-individual variability, the influence of circadian and pulsatile rhythms, nutrition and hydration status, climate, psychosocial factors and exercise characteristics, among others variables, may be factors that can influence the physiological status of the athletes and their performance [7, 20, 21, 22].

Thus, we should consider the principle of specificity as one of the key principles of physical training and monitoring. Based on it, a specific predesigned and monitored training stimulus will produce specific physiological responses that will generate specific training adaptations. Therefore, in the design of the training program in martial arts and combat sports, this principle should not be lacking because it establishes the need to distinguish the specific physiological characteristics of a particular style in order to adequately design and monitor a proper training program according to the specificity of this practice or sport [23, 24]. By monitoring the specific training load, coaches and scientific experts can be aware of the practitioner's appropriate adaptation to a certain level of effort, offering the opportunity to adjust the training stimulus to optimize the practitioner's physical and physiological adaptations to exercise [25]. For that reason, the knowledge about the physiological effects of the performance of the traditional *taolu* in a single kung-fu training session would be necessary to determine indicators as metabolic and cardiovascular demands, in terms of heart rate (HR) and blood lactate [$La^-$] responses, as stated in previous research [10, 19]. These indicators could be taken as objective measures of physiological responses in a specific

**Taolu** – discipline, a set of choreographed movements, called forms, can be performed empty-hand, with weapons, against other practitioners, against wooden dolls or using heavy bags. Taolu, refers to the set routine (form) practice component of wushu. Taolu routines comprise of a continuously connected set of pre-determined techniques, choreographed according to certain principles and philosophies which incorporate techniques and stylistic principles of attack and defense. These include hand techniques, leg techniques, jumps, sweeps, stances & footwork, seizing, throwing & wrestling, balances etc. Traditionally, Taolu routines were originally compiled to preserve the techniques and tactics of a particular lineage or system, and would gradually improve a practitioner's flexibility, stamina, strength, speed, balance and co-ordination, and would "imprint" a tactical order into practitioners. Taolu routines include individual routines and group routines, as well as partner/duel routines with 2 or more practitioners involved. They have a rich and diverse content utilizing a wide variety of techniques and includes both bare-handed routines and those performed with weapons [45] .

**Sanshou** or **sanda** – is a modern unarmed combat sport which developed from traditional wushu techniques, and primarily makes use of punching, kicking, throwing, wrestling and defensive techniques [45].

**Rating of perceived exertion (RPE)** – is a measurement tool that has been used by coaches and athletes to monitor the training load and to supervise the athlete's adaptation to their specific training. RPE is considered a useful measure that reflects the contractile state of the active muscles, as well as the physiological processes that underlie the development of muscular fatigue [27].

**Self-defence** *noun* fighting techniques used for defending oneself against physical attack, especially unarmed combat techniques such as those used in many of the martial arts [46].

**Training session** – *noun* a

martial art and combat sport training session [10, 11, 17, 18, 19].

On the other hand, subjective perceptual measures of effort are also valid and feasible tools for training monitoring, and they are relatively inexpensive and easy-to-use instruments compared to objective measures [25, 26]. In this sense, rating of perceived exertion (RPE) is a measurement tool that has been used by coaches and athletes to monitor the training load and to supervise the athlete's adaptation to their specific training. RPE is considered a useful measure that reflects the contractile state of the active muscles, as well as the physiological processes that underlie the development of muscular fatigue [27]. It has been found that RPE correlates with physiological markers such as oxygen consumption ($VO_2$), lactate accumulation, respiratory rate, and heart rate across a variety of exercise protocols [28, 29]. One of the most common tool used to evaluate RPE is the Borg scale (6-20) [27, 30]. In martial arts, several studies have already shown that the Borg scale is a valid and reliable scale to quantify the intensity of training during the performance of intermittent tasks, such as katas in karate [27, 31] whose training dynamics is the same as *taolu* performance in kung-fu.

*Taolu* can be performed both hitting a heavy bag or empty-hand, with repetitive high-intensity actions, explosive movements, and changes of directions. In addition, these actions require a certain control of breathing but always without losing fluency, in order to proper development of the technique. Nevertheless, the fatigue occurring during each execution of forms, which is individual and different for each practitioner, can interfere in this breathing control, worsening their performance and impairing the purpose of training. Furthermore, performing these forms hitting a heavy bag could vary the fatigue levels and could have different physiological effects than the empty-hand performance. However, the relationship between the metabolic, cardiovascular and perceptual responses of the martial art athletes when making a training session of *taolu*, performing empty-hand or hitting in a heavy bag, remains so far unknown.

The knowledge of this question could be of interest to martial arts and combat sport specialists who need a full understanding about the physiological indicators related with the fatigue to properly control and plan the training workload, in order to provide performance benefits for martial arts' athletes and also to improve long-term adherence or safety and injury prevention issues.

Therefore, the aim of this study was knowledge about acute heart rate (HR) and blood lactate [$La^-$] responses, and the rated perceived exertion (RPE) on the performance of empty-hand versus heavy bag *taolu* in amateur practitioners. We hypothesized that [$La^-$], HR and RPE values collected will be higher when performing the *taolu* training hitting in the heavy bag rather than when performing it in the empty-hand modality.

## MATERIAL AND METHODS

### Participants

Twelve male athletes from the amateur regional kung-fu team of southern Spain participated in this study (age 29.5 ±8.07 years; body mass 73.4 ±8.57 kg; height 1.73 ±0.057 m; BMI 24.4 ±2.52 $kg \cdot m^{-2}$; training days per week 2.42 ±0.51 days). Belt ranges associated with practitioners' level of experience oscillated from yellow fringe (>2 years of practice) to black fringe (>7 years of practice). The experience with the specific technique of exercise and the efficiency in the performance of forms were the key determinants for including the participants in the study. They were excluded if they suffered any pathology or injury, were taking any medication at the time of the study or had an inability or unwillingness to complete the study procedures.

Participants were informed about all experimental procedures, as well as the potential risks and benefits of this study. Each participant signed, prior to participation, a written informed consent form declaring that they have been informed and accepted their participation. The study was carried out according to the Declaration of Helsinki and was reviewed and approved by the University of Alicante Ethics Committee (UA-201 6-09-17).

### Equipment

All anthropometrical measures and physiological data were collected in laboratory conditions. Body mass was obtained to the nearest 0.1 kg using a balance beam (Avery Ltd. Model 3306 ABV), and height was measured using a stadiometer (Holtain Ltd.) to the nearest 0.5 cm. Then, participants were instrumented for telemetric HR assessment and informed about the [$La^-$]

period of time during which an athlete trains, either alone, with a trainer or with their team [46].

**Dynamic stretching** *noun* stretching that involves some movement but does not force the muscle past its range of motion [46].

**Static stretching** – *noun* stretching in which a position that stretches a muscle is assumed and then held [46].

**Borg Scale** – *noun* a scale on which the rate of perceived exhaustion is rated, from very light to exhausting [46].

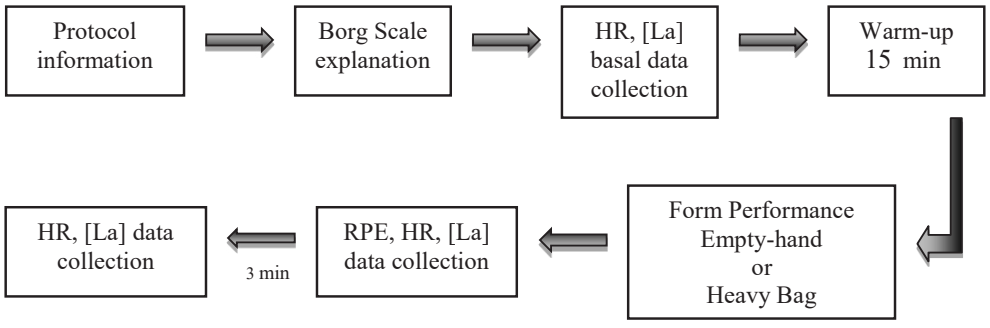



**Figure 1.** Scheme of study protocol.

data collection procedures. The HR was measured using a cardio tachometer (Suunto Ambit 3; Suunto. Oy, Vantaa, Finland), and [$La^-$] through a lactate analyzer (Lactate Scout; SensLab. GmbH, Leipzig, Germany). Capillary blood samples were collected from the earlobe in a seated position for the [$La^-$] data collection. Finally, participants were familiarized with a printed copy of Borg Scale (6-20) with the RPE levels associated with the numeric scale and illustrative images.

## Testing protocol

Trials were carried out in the morning in a randomized order for participants on two separate days with a 48h interval. Basal values of HR and [$La^-$] were measured just prior to start the warm-up and the study protocol. Post-exercise and 3-min post-exercise HR and [$La^-$] were registered after each performance of empty-hand or heavy bag *taolu*. RPE was also registered right after finishing each performance of the aforementioned study conditions. Exercise trials were performed according to the pre-established study protocol (Figure 1).

Accordingly, before performing each trial session, participants were familiarized with the instrumentations and the procedures. Afterwards, the participants warmed up for 15 minutes following a standardized guided plan, consisting on 10 minutes of general warm-up with static and dynamic stretching and 5 minutes performing specific kung-fu movements. After warm-up, participants were started with the pre-established exercise protocol. Thus, participants randomly carried out different kung-fu *taolu* during the trial, either hitting in a heavy bag or performing different empty-hand forms, seeking to obtain higher intensity levels in both performances. In one hand, athletes performed the same *Sah Bau Jong taolu* on heavy bag for five minutes long. In other hand, based on their belt grade and on their own experience and knowledge in this kung-fu style, each one performed one different empty-hand *taolu* also for five minutes long. Therefore, participants efficiently executed in randomized order *Ng Lun Ma*, *Sei Moon Kiu*, *Siu Mui Fa* or *Yee Jong Bot-Gwa Kuen* empty-hand *taolu* for five minutes and also *Sah Bau Jong* heavy bag *taolu* for five minutes long, throughout the trials, resting 10 minutes between both performances. The total duration of the *taolu* training session was 50 minutes approximately, within each trial session, including the data collection periods, 15 minutes of warm-up and 5 minutes of a cool- down. At the end of each *taolu* period and 3-min after the end of each *taolu* period, HR and [$La^-$] data were collected. Likewise, after each form performance, the participants reported the RPE values following the printed copy of Borg Scale, both the empty-hand forms and the heavy bag form. After each HR, [$La^-$] and RPE measurement, participants rested for 10 minutes. Throughout the development of the trials, in order to promote the appropriate level of effort in athletes, different kung-fu *taolu* videos were used motivating participants.

## Statistical analysis

All statistical data analyses were performed using SPSS 21.0 for Windows software (SPSS, Chicago, IL, USA). After checking the normality of the data (Kolmogorov-Smirnov), a general linear model with repeated-measures ANOVA was used to analyse the changes in the dependent variables studied (HR, [$La^-$] and RPE). Bonferroni post hoc tests

**Table 1.** Heart rate obtained values from participants (n = 12) during study conditions.

| Variable | Empty-hand forms | | | | Heavy bag forms | | | |
|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Mean | SD | Min. | Max. | Mean | SD |
| **HRbas** (b·min$^{-1}$) | 63 | 115 | 88.5 | 13.38 | 63 | 98 | 84.5 | 10.47 |
| **HRmax** (b·min$^{-1}$) | 177.03 | 192.79 | 185.59 | 5.53 | 177.03 | 190.73 | 184.22 | 4.75 |
| **HRWmean** (b·min$^{-1}$) | 145 | 182 | 169.16 | 7.92 | 161 | 182 | 171.37 | 7.74 |
| **HRWmax** (b·min$^{-1}$) | 156 | 189 | 177 | 7.37 | 169 | 188 | 177.75 | 7.16 |
| **HRres** (b·min$^{-1}$) | 63.4 | 127.73 | 97.09 | 16.56 | 79.03 | 127.73 | 99.72 | 14.24 |
| **HRWmean** (%) | 50.63 | 106.29 | 84.63 | 16.56 | 72.14 | 105.02 | 88.09 | 10.15 |
| **HRWmax** (%) | 63.03 | 115.15 | 92.54 | 15.05 | 82.98 | 113.88 | 94.58 | 10.20 |

**HRbas** – Basal Heart Rate; **$HR_{max}$** – formula of Inbar et al. (1994): **$HR_{max}$** – 205.8-0.685(age); **$HRW_{mean}$** – mean of Heart Rate Work; **$HRW_{max}$** – Maximal Heart Rate Work; **$HR_{res}$** – Heart Rate Reserve (HRmax - HRbas).

were used for pair-wise comparisons. Statistical significance was set at p<0.05. All variables are reported as mean ± SD.

## RESULTS

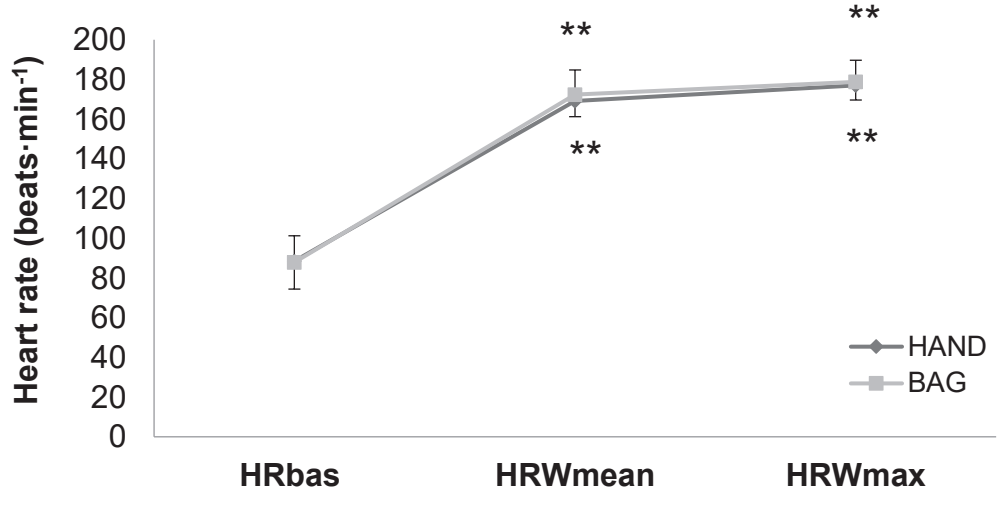
### Heart Rate Outcomes

The different obtained values of heart rate (HR) from study conditions were presented in Table 1.

Significant differences were found between $HR_{bas}$ vs. $HRW_{mean}$ (p = 0.000) and $HR_{bas}$ vs. $HRW_{max}$ (p = 0.000) (Figure 2). No significant differences were found between two analysed conditions in $HRW_{mean}$, p = 0.659; $HRW_{max}$, p = 0.574; $\%HRW_{mean}$, p = 0.605; $\%HR_{max}$, p = 0.742.

### Blood Lactate Concentration

Also, the lactate responses after trial conditions were 1.67 ± 0.61 mmol·L$^{-1}$ from basal values ($[La^-]_{basal}$); 9.75 ±5.32 mmol·L$^{-1}$ from post-exercise values $[La^-]_{post}$ and 9.091 ±5.3 mmol·L$^{-1}$ from 3 minutes after exercise values ($[La^-]_{3'}$) in the




**$HR_{bas}$** hart rate basal values; **$HRW_{mean}$** hart rate post-exercise mean values; **$HRW_{max}$** hart rate post-exercise maximal values; ****$HR_{bas}$ vs. $HRW_{mean}$** p = 0.000; ****$HR_{bas}$ vs. $HRW_{max}$** p = 0.000

**Figure 2.** Comparison of heart rate responses in male athletes (n = 12) after performance of empty-hand forms vs. heavy bag forms.

empty-hand condition and 1.7 ±0.65 mmol·L$^{-1}$, 10.74 ±4.54 mmol·L$^{-1}$, 11.00 ±5.62 mmol·L$^{-1}$ respectively in heavy bag condition. These outcomes showed significant differences on blood lactate between basal values ([La$^-$]$_{basal}$) and post-exercise values ([La$^-$]$_{Post}$), (p = 0.000) and significant differences between basal values ([La$^-$]$_{basal}$) and 3 minutes after exercise values ([La$^-$]$_{3'}$), (p = 0.000) (Figure 3). Also, no significant differences were found in blood lactate responses, both [La$^-$]$_{post}$ (p = 0.658) and [La$^-$]$_{3'}$ (p=0.436), between the two analysed forms.

### Rating Perceived Exertion

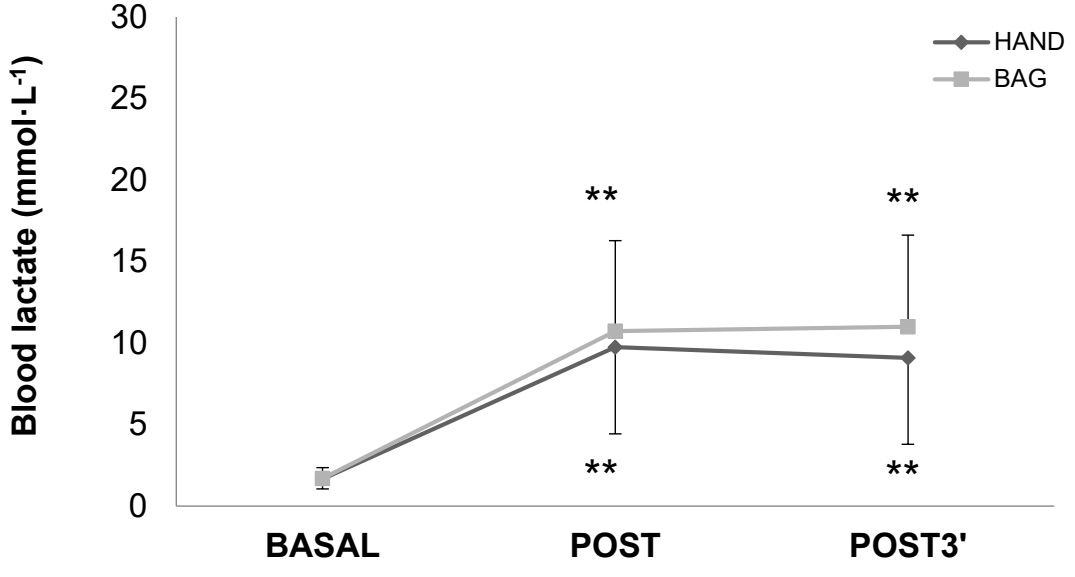
Regarding the RPE values reported by study participants, no significant differences (p = 0.068) were found between empty-hand (14.92 ±1.78 RPE) vs. bag (16.17 ±1.80 RPE) forms performance.

## DISCUSSION

Results did not support our initial hypothesis and showed no significant differences between the performance of empty-hand and in heavy bag forms, measured by objective physiological indicators of exertion (HR and [La]), and subjective indicators of effort (RPE). In our hypothesis, we proposed that all values collected will be higher when performing the *taolu* training hitting the heavy bag rather than when performing it in the empty-hand modality. However, the study data indicated that the cardio-metabolic workload of the trial remained high in both conditions, coinciding with the subjective evaluation of exertion made by athletes in both experimental conditions. Therefore, these results suggest that the performance of *taolu* using heavy bag does not represent a higher cardiovascular and metabolic stress, nor higher subjective perception of effort, for martial arts' athletes, compared to the performance of empty-hand *taolu*.

The present study revealed that HR and [La$^-$] values reached in both study conditions were elevated. Thus, the workload intensity achieved on performed session can be considered as vigorous [32], due to these high cardio-metabolic responses observed in participants, and also due that this increase of HR and [La$^-$] post-exercise values regarding baseline values were significant (p<0.000). These findings are consistent with previous research evaluating HR [10, 31, 33, 34] and [La] [10, 17, 18, 35] during combats or training sessions of other combat sports.

Regarding to HR results, Inamura et al. [34]




**BASAL** basal values; **POST** post-exercise values ([La]$_{post}$); **POST3'** 3 minutes post-exercise values ([La]$_{3'}$). ****[La]$_{Basal}$** vs. **[La]$_{Post}$** p = 0.000; ****[La]$_{Basal}$** vs. **[La]$_{3'}$**, p = 0.000

**Figure 3.** Comparison of blood lactate concentration in male athletes (n = 12 )after performance of empty-hand forms vs. heavy bag forms.

demonstrated in one study evaluating this physiological parameter after performance of punching and kicking techniques that athletes attained 85.5% and 90.1% of $HRW_{max}$, respectively. Ribeiro et al. [10] demonstrated in other study evaluating the same indicator after performance of *taolu* training session in modern wushu that athletes attained 89.1% of age-predicted $HRW_{max}$. Other researchers [31, 36] who directly analysed the cardiovascular responses of practitioners while performing specific techniques and forms from karate, observed that the intensity of HR ranged between 70.7% and 93.2% of $HRW_{max}$. In our study, HR values reached 84.63% of $HRW_{mean}$, and 92.54% of $HRW_{max}$ in the empty-hand performance; and 88.09% of $HRW_{mean}$, and 94.58% of $HRW_{max}$ in the heavy bag performance. These values are very similar to those shown in the commented studies. According to the American College of Sports Medicine (ACSM), in relation with the principle of training overload, a minimum threshold of intensity is needed to improve maximal oxygen uptake ($VO_2max$), as well as other physiological indicators [32]. Within the classification developed by ACSM to estimate the relative intensity of exercise for cardiorespiratory fitness, it has been established in a range of 77-95% $HRW_{max}$ as a range of vigorous exercise intensity [32]. Therefore, the HR values found in both study conditions would be within this range of vigorous intensity.

Regarding [$La^-$] results, with the elevated [$La^-$] data obtained, we can infer that there was a significant activation of the glycolytic pathway during the performance of forms in all the participants, both hitting the heavy bag and performing the empty-hand modality, considering that the anaerobic threshold has been established in previous studies in 4 mmol·$L^{-1}$ [37]. We can also assume that the high values of [$La^-$] and HR achieved during the trials indicate a high cardio-metabolic workload, considering that the indicated anaerobic threshold and the blood lactate curve are valid indicators of endurance performance [38]. Our results are in line with previous research evaluating these [$La^-$] responses in martial arts. The study of Artioli et al. [14] showed similar results to those analysed in our study, with [$La^-$] concentrations of 10.8 ±2.0 mmol·$L^{-1}$ in men after wushu combat and *taolu* training. Accordingly, Del Vecchio et al. [39] showed 10.2 ±1.5 mmol·$L^{-1}$ after a Brazilian jiu-jitsu fight. Heller et al. [35] also reported 11.4 ±3.2 mmol·$L^{-1}$ during a taekwondo fighting. Slightly lower [$La^-$] values (7.5 ±3.8 mmol·$L^{-1}$) were found in other study [40] with taekwondo athletes in a competition. However, our session of forms, in both conditions analysed, seems to be more anaerobic demanding session compared with the performance of forms in modern wushu, investigated by Ribeiro et al. [10]. Therefore, based on the ACSM's classification [32] and previous studies analysed, it can be concluded that the intensity of both conditions performed in our study were vigorous and metabolic-demanding, and, thus, this *taolu* training session would be adequate for developing and improving cardiorespiratory fitness in kung-fu athletes. In addition, in our investigation, we analysed, from each study condition, the RPE responses, in order to examine whether there was a relationship between physiological and perceptual indicators of exertion when performing a session of kung-fu *taolu*.

Previous research [28, 29, 31, 33, 34] already showed the efficacy of RPE to predict the training intensity in resistance training and martial arts, and also to quantify the training intensity during non-steady state and prolonged exercise. Therefore, RPE can be used to measure intensity indicators of physical activity and to correlate them with physiological indicators such as HR and [$La^-$], and thus, to know the practitioner's effort from their subjective perception. In our study, participants reported intense and very intense RPE values, from both study conditions, which indicates, from a perceptual measurement standpoint, a high intensity training session. Further, no significant differences were found between the RPE values reported after empty-hand *taolu* and heavy bag *taolu* performances ($p = 0.068$). Thereby, it also would support that performing forms, both using heavy bag or empty-hand, could be a valid training session to improve fitness in kung-fu athletes, as already showed previous research [10, 19]. Similar values were found in one study [41] measuring RPE responses from mixed martial arts athletes in training and competition, reaching RPE levels ranged from 15 to 19 on Borg's Scale. However, the RPE values obtained in our study were somewhat higher than those assessed by Bridge et al. [42], during an international competition of taekwondo, and Chaabène et al. [43], in a national-level competition of karate, which obtained 13 ±2 and 14 ±2 on the Borg Scale, respectively. Thus, regarding to the obtained RPE values, it can be concluded that, from participants' perception, to perform the kung-fu forms hitting the

heavy bag supposes the same effort than to perform them empty-hand, corresponding this RPE with the levels of intense and very intense effort, based on the Borg Scale.

## CONCLUSIONS

The practical applications of these findings are the different possibilities of training that presents the performance of *taolu*, with or without using heavy bag indistinctly, since the results when performing empty-hand and bag *taolu* are similar, in terms of physiological and perceptual effects. Thus, martial arts' athletes who cannot hit the heavy bag, either because of an injury or because it is not easily available, can perform only empty-hand forms, obtaining the same physiological benefits as if they were performed the forms in the heavy bag, and thereby extending the training offer in areas where they do not have a heavy bag. More studies are needed to investigate whether training on heavy bag, apart from the physiological benefits already studied, could improve certain patterns of applied technique, proprioception and kinematics of *taolu*, and provide other perceptual-motor related benefits.

Future research is necessary to complete the knowledge of the profile of kung-fu athletes, on indicators like anthropometric and nutritional profiles, muscle power and maximal dynamic strength, aerobic and anaerobic profile, flexibility, energetics, incidence of injuries, and finally reaction time, as it has already been investigated in other combat sports [14, 35, 44]. Furthermore, new studies are needed to gather information on the acute physiological demands of athletes while performing forms and applications in pairs, as well as during combat, especially with respect to multiple fights and also in competitive environments. This study, despite to provide novel data regarding physiological and perceptual strain in kung-fu practice, it also presented several limitations. Firstly, the relatively small sample size and also the heterogeneity of the sample investigated (age, experience levels) could lead to underestimation of the results. Finally, comparison of our findings with the martial arts' literature was limited, because the empirical studies analysed were limited in number and quality, which demonstrates the lack in martial arts research and highlights the need to develop and expand a more robust research in this widespread area of sport.

The comparison of acute cardio-metabolic responses on HR and [La], and the acute perceptual responses on RPE after performance of empty-hand versus heavy bag *taolu* in kung-fu athletes showed that the intensity of the both conditions performed in our study was vigorous and metabolic-demanding, and, accordingly, the exertion was perceived as intense or very intense by the participants. Therefore, these results suggest that the performance of *taolu* using heavy bag does not represent a higher cardiovascular and metabolic stress, nor higher subjective perception of effort, for kung-fu athletes, compared to the performance of empty-hand *taolu*.

## ACKNOWLEDGEMENTS

The authors would like to thank José Luis Sala, president of KF *LONG MEN PAI* Club of Alicante (Spain) as well as the participants for their time and effort.

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**Cite this article as:** Cortell-Tormo JM, García-Jaén M, Gómez-Ramos J et al. Physiological and perceptual responses for specific taolu exercises (empty-hand versus heavy bag performance). Arch Budo 2018; 14: 329-337