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# Heart Rate Responses to Taekwondo Training in Experienced Practitioners

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**Abstract.** Bridge, C.A., M.A. Jones, P. Hitchen, and X. Sanchez. Heart rate responses to Taekwondo training in experienced practitioners. *J. Strength Cond. Res. 21(3):718–723. 2007.*—The purpose of this study was to evaluate the heart rate (HR) responses of specific Taekwondo training activities, practiced by experienced practitioners in a natural training environment. Eight male experienced Taekwondo practitioners, with 3–13 years (5.4 ± 3.2 years) experience took part in a 5-day Taekwondo training camp. Continuous HR measures were recorded at 5-second intervals during 6 training sessions; each session was observed and notated, and a diary of training activities was recorded. The HR responses were assimilated into 8 fundamental training activities for analysis: elastics, technical combinations, step sparring, pad work, forms, basic techniques and forms, sparring drills, and free sparring. Taekwondo training elicited HR into 64.7–81.4% of HR maximum (%HRmax). Moderate relative exercise intensities (64.7–69.4%HRmax) were elicited by elastics, technical combinations, and step sparring. The remaining 5 training activities elicited hard relative exercise intensities (74.7–81.4%HRmax). One-way repeated-measures analysis of variance with post hoc analysis revealed that elastics, technical combinations, and step sparring elicited significantly lower relative intensities than the remaining training activities ($p < 0.05$). Furthermore, forms, basic techniques and forms, sparring drills, and free sparring elicited significantly higher relative intensities than the remaining training activities ($p < 0.05$). In conclusion, all Taekwondo training activities in this study seemed suitable for cardiovascular conditioning, although different training activities stressed the cardiovascular system to different degrees. Practically, this suggests coaches need to structure Taekwondo training sessions based not only on the technical and tactical needs of practitioners but also in a manner that enables sufficient cardiovascular conditioning for competition.

Key Words. martial art, cardiovascular fitness, intermittent exercise, high intensity

## Introduction

Taekwondo has evolved from traditional martial art to modern day Olympic sport, and the global population of practitioners is now estimated at >50 million people (14, 20) extending across 179 nations (33). Inevitably, the transition to Olympic sport has imposed increased demands on athletes during competition (12). Despite this, there is little evidence to indicate that training practices have altered to accommodate for these increased demands. For instance, the $\dot{V}O_2$max of Taekwondo practitioners has been repeatedly reported as low compared with other athletic groups (3, 12, 29). Consequently, it seems necessary to establish whether conventional training activities elicit suitable cardiovascular stimulus to generate the desired adaptations to enhance competitive performance. Greater understanding of the cardiovascular responses elicited by specific training activities will assist coaches in the optimization of sport-specific training programs.

Taekwondo training sessions can include any of the following conventional activities: basic techniques, technical combinations, predetermined sequence of movements (forms or poomsae), breaking techniques, self-defense techniques, step sparring, sparring (skill) drills, and free sparring (14, 18, 20, 32, 33). Although Taekwondo training can be highly variable, the same fundamental 8 activities are universally practiced, with the inclusion of some supplementary methods, such as the use of pads and elastics for additional resistance (20, 26). Nevertheless, little research exists regarding the typical training regimens of experienced Taekwondo athletes. Consequently, understanding of the heart rate (HR) responses to existing Taekwondo training activities is limited. Existing evidence suggests that participation in Taekwondo forms (≈80% of HR maximum [%HRmax]), kicking and punching technical combinations (≈90%HRmax), and simulated dynamic sessions (88.3–92.2%HRmax) elicit HR into cardiovascular training zones (27, 31). These exercise intensities fall well within the range for improving and maintaining cardiovascular fitness in healthy adults (55–90%HRmax) and are typically classified as hard or very hard relative exercise intensities (2).

Existing Taekwondo data should be interpreted with caution because protocols lack ecological validity. The term "ecologic validity" in this setting refers specifically to the interaction of Taekwondo athletes with their natural environment and practices. Protocols have often involved training simulations in laboratory environments, using inexperienced participants and unrealistic work to rest ratios, number of actions, durations, and intensities of practice (27, 31). Consequently, existing research (27, 31) may provide a misleading representation of the HR responses to traditional and competitive Taekwondo training in a ecologically valid setting. To ensure ecologic validity, future evaluations should incorporate field assessments, using realistic work to rest ratios, number of actions, intensities, and durations of practice. Finally, the structure and proportion of activities within typical training environments should also be taken into consideration within ecologically valid assessments.

The purpose of this study was to evaluate the HR responses of specific Taekwondo training activities practiced by experienced practitioners in an ecologically valid training environment. The hypotheses were (a) ecologically valid Taekwondo training activities will elicit HRs to within recognized cardiovascular training zones, although the relative intensities will be lower than reported with previous laboratory simulations; (b) the relative exercise intensities elicited by sparring related activities will be greater than other technique practices; (c) the relative exercise intensities elicited by activities will be insufficient to elicit the cardiovascular stimulus required for competition conditioning; and (d) the total duration of activity practices during a typical training session will fall within recommended guidelines identified by the

American College of Sports Medicine (ACSM) for improving and maintaining cardiovascular fitness (2).

## METHODS

### Experimental Approach to the Problem

To evaluate the cardiovascular responses of conventional Taekwondo activities practiced in an ecologically valid setting, HR was recorded during a typical Taekwondo training camp. To enhance the ecologic validity and reliability of the measurements, data were recorded from a number of different sessions across the training camp. Although Taekwondo training can be highly variable, the same fundamental 8 activities are universally practiced (14, 18, 20, 32, 33). The HR responses from the entire training camp were assimilated into these 8 fundamental activities. This enabled the authors to study whether conventional activities elicited HR to within recognized cardiovascular training zones, to identify the relative exercise intensities elicited by each activity, and to specify activities suitability for competition conditioning. The above information will permit coaches to optimize the design of competition-specific training sessions. HR is a noninvasive measure that has frequently been used as a reliable index of relative exercise intensity during a variety intermittent training and competition environments (6, 7, 12, 27). Furthermore, the reliability and validity of polar chest electrodes have been established against electrocardiogram across a range of exercise intensities (1).

To further ensure ecologic validity, 2 highly experienced (>35 years of practice each) international coaches (Fourth Dan Black Belt) with a World Taekwondo Federation (WTF) refereeing certification (at national and international levels for both poomsae and kyorugi) delivered the training sessions. All techniques were practiced on the coaches' command, and sessions were not manipulated by the researchers in any manner in an attempt to obtain realistic work to rest ratios, durations, and intensities of practice. Taking an ecologically valid approach to HR assessment also ensured that the structure and proportion of activities within typical training environments were evaluated in this study. This enabled the authors to identify whether the total duration of activity practices during each session fell within the ACSM's recommended guidelines for improving and maintaining cardiovascular fitness (2). The rationale for the inclusion of a homogenous sample of experienced participants was based on the premise that experienced athletes have improved economy of movement (19, 24). Consequently, experienced and trained athletes are able to work at a lower relative intensity (HR) to produce the same work output (8, 19, 24), and it is these athletes who are regularly competing within competition training.

### Subjects

Eight male Taekwondo practitioners with 3–13 years of experience (5.4 ± 3.2 years), including 5 Dan grades ranging from Fourth to First Dan, 2 First Keup grades, and 1 Third Keup grade took part in the study. Six of the 8 subjects were regularly competing in kyorugi, forms, or a combination of both at WTF national (e.g., several medallists at French Championships) and international (e.g., 2 silver medals at World Championships) events. Subjects' typical training regimen before the training camp included set training sessions of 3 days per week, ≈2 hours in duration, often with the inclusion of further sessions of personalized work as necessary (range, 6–10 hours per week). At flexible intervals in the training calendar, subjects were required to attend specific training camps; in this case, typically across 5 days, involving 2 daily sessions. Taekwondo training was the only active form of training for these subjects, with some general light cardiovascular work incorporated within these sessions. Subjects' mean ± *SD* age, mass, and height were 22.5 ± 4.1 years, 70.5 ± 15.8 kg, and 1.77 ± 0.10 m, respectively. The project was conducted in accordance with Edge Hill University Ethics Code of Conduct, all subjects were informed of the test procedures and potential risks, and informed consent was attained from all participants.

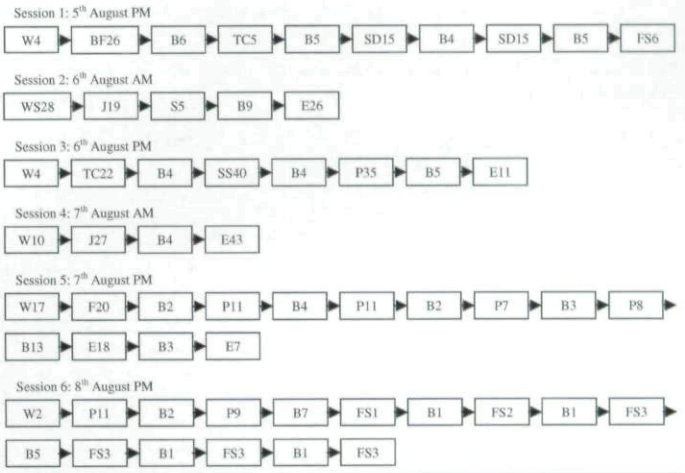


**FIGURE 1.** Structure of recorded training activities. Numbers represent training time in minutes; letters represent each activity. W = warm up; B = break; J = jog; S = stretch; E = elastics; SS = step sparring; TC = technical combinations; P = pad work; F = forms; BF = basic technique and forms; SD = sparring drills; FS = free sparring.

### Procedures

Subjects took part in a 5-day Taekwondo training camp consisting of 2 daily sessions. The goal of the training camp was to satisfy the demands of Taekwondo, including desired physical components of fitness such as strength, power, speed, competition-specific (cardiovascular) conditioning, etc., and relevant technical and tactical aspects. Daily sessions typically included a morning (≈0630–0800 hours) and an evening session (≈1600–1800 hours), with ≈8 hours separating each session. Continuous HR measures were taken at 5-second intervals during 4 evening sessions and 2 morning sessions using the Polar Team System (Polar Electro Ltd, Warwickshire, UK; see Figure 1 for the structure of recorded training activities). In total, 570 minutes of data were successfully recorded, each training session was observed and notated, and a diary of activities was recorded. HR data was downloaded using Polar precision software (version 4.0), and mean HRs for the 8 different training activities were categorized and analyzed. Maximum HR was estimated using the standard equation of 220 − age.

### Recorded Training Activity Categories

Taekwondo training sessions typically include a combination of the following conventional activities: basic techniques, technical combinations, predetermined sequence of movements (forms), breaking techniques, self-defense techniques, step sparring, sparring (skill) drills, and free sparring (14, 18, 20, 32). During the training sessions, the

**TABLE 1.** Definition of recorded training activity categories.

| Activity | Definition |
|---|---|
| Basic technique and forms | The interchangeable practice of single punching, kicking, and form techniques on the coaches' command. Basic techniques are also known as fundamental techniques. |
| Technical combinations | A variety of basic kicking techniques executed in various combinations. A combination is 2 or more basic techniques executed continuously. |
| Forms | Predetermined sequences of movement that range in complexity and length. Forms are practiced either completely or are broken down into smaller segments on coaches command. Also known as poomsae and patterns. |
| Step sparring | One step prearranged attacks with random counterattacks performed for coach defined periods. Roles are reversed on the coaches' command. |
| Sparring drills | Prearranged attacking and counterattacking kicking drills practiced repeatedly in pairs making contact with body armour for resistance. Also known as skill drills. |
| Free sparring | Open combat between 2 participants in a free-moving situation (non prearranged). Free sparring is usually performed for coach defined periods of time, sometimes in a manner that simulates competition. Also known as contact sparring. |
| Elastics* | Basic techniques including punches and kicks are practiced continuously utilizing elastic stretch bands for additional resistance. Elastic stretch bands are attached to appropriate body segments and single basic techniques are executed in a repetitive manner for coach-defined periods. |
| Pad work* | The practice of technical combinations that make contact with pads for additional resistance. |

* Conventional training activities were modified with the inclusion of additional resistance.

authors notated when each of the 8 categories were practiced in accordance with the above-mentioned defined activities, and a diary of activities was recorded. During the sessions, breaking techniques and self-defense techniques were not practiced; therefore, they were not included as categories in this study. Two additional categories were included because the conventional activities, basic techniques, and technical combinations were modified by the inclusion of elastics and pads for additional resistance. In 1 session, basic techniques were practiced interchangeably with forms and were thus grouped accordingly. Consequently, the following 8 activity categories were included for analysis: basic techniques and forms, technical combinations, forms, step sparring, sparring drills, free sparring, elastics, and pad work (see Table 1 for the definition of recorded training activities).

### Statistical Analyses

One-way repeated-measures analysis of variance (ANOVA) was conducted to compare the HR responses to different activities. When significant treatment effects were identified, related *t*-tests were conducted to allow pairwise comparisons. Significance was set at $p \leq 0.05$, and the observed power and effect size for the number of subjects ($n = 8$) was 0.95 and 0.83, respectively. Descriptive data are expressed as mean ± *SD*. All statistical procedures were performed using SPSS for windows (version 11.5; SPSS, Inc., Chicago, IL).

## RESULTS

Taekwondo training elicited HRs into 64.7–81.4 %HRmax, although different activities seemed to stress the cardiovascular system to different degrees (Table 2). A one-way repeated-measures ANOVA identified a significant difference in cardiovascular responses between these activities ($p < 0.05$). The practice of elastics, technical combinations, and step sparring elicited similar mean HR responses ($p > 0.05$). However, these responses were significantly lower ($p < 0.05$) than HR responses elicited by the remaining activity practices. The practice of pad work elicited a significantly greater ($p < 0.05$) mean HR response than practice of elastics, technical combinations, and step sparring practices. Nevertheless, mean HR responses reported with pad work were significantly lower ($p < 0.05$) than the responses elicited with the practice of forms, basic technique and forms, sparring drills, and free sparring. The practice of forms, basic technique and forms, sparring drills, and free sparring seemed to elicit similar cardiovascular demands ($p > 0.05$), and these were significantly greater than the remaining activity practices ($p < 0.05$). No significant differences were found between free sparring modes ($p > 0.05$).

Each of the 6 training sessions recorded were identified as having accumulated Taekwondo training activities of sufficient duration to elicit cardiovascular training adaptations (26–108 minutes). However, the accumulated duration of individual activities during each session was sometimes less than the minimum of 20 minutes recommended (2) for eliciting cardiovascular training adaptations (Table 2). Mean session HRs were also within the recognized range for cardiovascular conditioning (119.9 ± 10.3 to 169.0 ± 10.8 b·min$^{-1}$). One of the training sessions did elicit an average HR at the lower end of the threshold (119.9 ± 10.3, 55–65% HRmax), whereas the remaining sessions were well within the recommended guidelines (134.7 ± 11.0 to 169.0 ± 10.8 b·min$^{-1}$, 65–90% HRmax).

## DISCUSSION

The findings of this study showed that Taekwondo training in an ecologically valid setting elicited HRs into 64.7–81.4%HRmax. All activities elicited intensities sufficient for developing and maintaining cardiovascular fitness in healthy adults (55–90%HRmax) (2). Considerable disparity was identified between the relative intensities elicited by this field-based study (64.7–81.4%HRmax) and previous simulations of Taekwondo practice (79.7–92.2%HRmax) (27, 31). Disparity between findings may be caused by differences in the complexity of technical routines, experience, and training status of participants (8, 19, 24) and the ecologic validity of test protocols. Pieter et al. (27) used laboratory evaluations that simulated unrealistic work to rest ratios, durations, and number of actions. Variations in work to rest ratios, durations, and number of actions can significantly alter the mean HR response (5, 21, 28). Toskovic et al. (31) evaluated a lab-

**TABLE 2.** Heart rate responses and typical duration of Taekwondo training activities.*

| Taekwondo activity | HR ($b \cdot min^{-1}$) | %HRmax† | Relative exercise intensity‡ | Total duration over training camp (minutes) | Percent total time | Duration over each session (minutes)§ |
|---|---|---|---|---|---|---|
| Elastics | 127.8 ± 12.9‖ | 64.7 ± 6.0 | Moderate | 105 | 18.6 | 11–43 |
| Step sparring | 133.0 ± 16.2‖ | 67.2 ± 9.8 | Moderate | 40 | 7.1 | 40 |
| Technical combinations | 137.4 ± 18.3‖ | 69.4 ± 8.4 | Moderate | 27 | 4.8 | 5–27 |
| Pad work | 148.0 ± 15.0¶ | 74.7 ± 7.6 | Hard | 91 | 16.1 | 20–36 |
| Forms | 157.0 ± 18.6# | 79.6 ± 9.2 | Hard | 20 | 3.5 | 20 |
| Basic techniques and forms | 157.6 ± 24.3# | 79.8 ± 11.4 | Hard | 26 | 4.6 | 26 |
| Sparring drills | 160.0 ± 17.4# | 80.8 ± 8.6 | Hard | 30 | 5.3 | 30 |
| Free sparring | 160.6 ± 15.3# | 81.4 ± 7.0 | Hard | 21 | 3.7 | 6–15 |
| Entire training camp activities | 147.7 ± 13.2** | 74.6 ± 6.7 | Hard | 360†† | 63.6†††‡‡ | — |

* Data are mean ± *SD* unless stated otherwise. HR = heart rate.

† %HRmax calculated with equation 220 − age.

‡ Relative exercise intensity based on %HRmax on physical activity lasting up to 60 minutes (2).

§ Data are range the of times practice during individual sessions.

‖ No significant difference in mean HR between these activities ($p > 0.05$), although these activities elicited significantly lower mean HR than all the remaining activities ($p < 0.05$).

¶ Mean HR significantly higher ($p < 0.05$) than elastics, step sparring, and technical combinations, but significantly lower ($p < 0.05$) than forms, basic technique and forms, sparing drills, and free sparring.

# No significant difference in mean HR between these activities ($p > 0.05$), although these activities elicited significantly higher mean HR than all the remaining activities ($p < 0.05$).

** Data not included in statistical analysis.

†† Data are the sum of the above values.

‡‡ Remainder of total time comprised of breaks (16.6%), warm-up (10.7%), and light-intensity running (8.9%).

oratory simulated "Dynamic Taekwondo session." Dynamic Taekwondo is more cyclic in nature (31), possibly allowing greater steady-state HRs. This highlights the importance of an ecologic approach with future HR evaluations of specific training activities.

Technical practices including elastics, step sparring, and technical combinations elicited moderate intensities. These findings may suggest a greater emphasis on power and correct technique rather than cardiovascular demand. The practice of technical combinations with pads for additional resistance significantly increased the mean HR response from moderate to hard relative exercise intensities, suggesting that athletes may benefit from greater cardiovascular gains with the inclusion of additional resistance during practices. The cardiovascular responses to technical combinations in this study (69.4%HRmax) were considerably lower than reported by previous research (90.5%HRmax) (27). The accumulated practice duration of these activities over each training session seemed to satisfy the current guidelines for improving and maintain cardiovascular fitness (≥20 minutes), with the exception of 1 elastics session (11 minutes) and 1 technical combination session (5 minutes). Although the current ACSM's cardiovascular conditioning guidelines are based on studies investigating various exercise modes, it seems pertinent to apply these guidelines until further evidence is apparent from sport-specific conditioning studies. The only existing Taekwondo-specific study suggested that forms training ≤10 minutes was insufficient to elicit cardiovascular adaptations (23).

The practice of forms, basic technique, and forms practiced interchangeably elicited significantly greater cardiovascular demands than elastics, step sparring, technical combinations, and pad work. This may suggest that such practices are more effective at targeting and developing correct technique while maximizing cardiovascular fitness. Nevertheless, the practice of forms over an 8-week period produced no improvements in $\dot{V}O_2max$ (23), suggesting that the effects on cardiorespiratory fitness are negligible. However, the authors included an homogenous sample of adolescent boys, an insufficient forms protocol for the experience of participants, and the duration of the forms protocol failed to meet the minimum duration required for improving cardiovascular fitness (2, 23). The findings of our study are comparable with the practice intensity of forms in previous Taekwondo research (≈80%HRmax) (27). The practice duration of forms, basic techniques, and forms over each session satisfied the current cardiovascular conditioning recommendations; however, these were at the lower end of the recommended duration (20–26 minutes).

The practice of sparring drills (80.8%HRmax) and free sparring (81.4%HRmax) elicited the greatest demands on the cardiovascular system. It may be pertinent to suggest that sparring drills and free sparring are most suitable for developing and maintaining cardiovascular fitness necessary for competition conditioning. Nevertheless, previous research has reported substantially higher HR responses to actual Taekwondo competition (≈100%HRmax), although different methods were used to determine %HRmax (12). These differences may be because of variations in psychologic stress between competition and training environments, variations in fitness status between studies, or the inappropriateness of training to emulate the demands of competition. The potential of psychologic stress to influence HR during competition has been highlighted previously in analogous combat sports such as karate, where competition presparring HR was typically 15.7% higher ($13.7\ b \cdot min^{-1}$) than training presparring HR (17). Further evidence of psychologic stress is apparent from the presence of precompetitive state anxiety (somatic and cognitive dimensions) during Taekwondo competition (9).

Although sparring drills and free sparring seem to be the most suitable activities for competition conditioning, the percentage of time attributed to these activities during each session was small. In addition, the practice du-

ration of free sparring during each session was often below the minimum duration of 20 minutes required to improve and maintain cardiovascular fitness (2). If this trend is similar across the Taekwondo community, the intensity of both these activities and the duration of free sparring seem to be insufficient to produce the desired training stimulus for competition conditioning. This may partly explain the low $\dot{V}O_2$max values of some traditional Taekwondo athletes (44.0–53.9 $ml \cdot kg^{-1} \cdot min^{-1}$) (12, 29).

In an attempt to maintain ecologic validity, HR measurements in this study were recorded without concomitant measurements of $\dot{V}O_2$. The independent use of HR to estimate relative exercise intensity should be approached cautiously. Although HR and $\dot{V}O_2$ are linearly related across a large range of submaximal intensities, it has been well documented that HR responses in many martial art activities are inordinately high for a given $\%\dot{V}O_2$max during continuous incremental exercise (15, 16, 28, 31, 34). Similar responses have been reported with numerous intermittent exercise environments, with overestimations ranging from 4.3 to 20.7% of $\dot{V}O_2$ (4, 5, 10, 22, 25). In martial art environments, HR overestimations have been attributed to the static nature of arm and leg movements or the arm movement itself (small muscle mass) (28, 31, 34), which seems conceivable (13, 30). However, HR overestimations may also be attributed to emotional factors, thermal stress, and the failure of HR to show appreciable recovery between work intervals (6, 11). In light of this, it seems plausible to suggest that similar responses may translate to Taekwondo training activities in this study. This implies that the cardiorespiratory adaptations anticipated with the practice of activities at specific HR intensities may not be fully quantified. Nevertheless, it remains feasible to make comparisons between competition and training HR stimuli, because the proposed mechanisms are likely to pose similar influences in both situations. The major influential factor seems to be the psychophysical influences (9, 17).

To conclude, all ecologically valid Taekwondo activities in this study seemed to elicit intensities suitable for cardiovascular conditioning. However, different activities stressed the cardiovascular system to different degrees, with sparring activities eliciting the greatest HR responses. The accumulated duration of cardiovascular stimulation within individual training sessions were sufficient for cardiovascular conditioning. However, based on previous competition research and current cardiovascular conditioning guidelines, it seems that the intensity of these activities and the duration of some activities such as free sparring may have been insufficient to elicit the cardiovascular stimulus required for competition.

## Practical Applications

The findings of this study suggest that coaches need to structure Taekwondo training sessions based not only on the technical and tactical needs of practitioners but also in a manner that enables sufficient cardiovascular conditioning for competition. Of the 8 typical Taekwondo training activities, elastics, step sparring, and technical combinations elicited HR into moderate relative exercise intensities. While the above-mentioned activities may be pertinent for developing technical and tactical aspects and/or other fitness components such as strength and power, they provide only a moderate stimulation to the cardiovascular system. Their practice might, therefore, be best suited within sessions around blocks of other higher intensity activities to ensure a rounded conditioning session. Furthermore, coaches may consider using technical training activities that elicit moderate cardiovascular intensities for recovery training sessions. The addition of further resistance to technical combinations enhances the cardiovascular stimulus, and therefore, coaches might consider the use of pads to increase cardiovascular training effects if appropriate.

The remaining 4 of the 8 typical Taekwondo training activities, including forms, basic techniques and forms, sparring drills, and free sparring, elicited hard relative exercise intensities, suggesting they are suitable to elicit cardiovascular training adaptations. In contrast, however, the cardiovascular responses of these training activities failed to elicit relative exercise intensities sufficient for competition conditioning, which typically yielded very hard to maximal intensities. Coaches might, therefore, need to reconsider competition-specific training methods and sessions to ensure optimal conditioning for competition performance. For example, coaches should be made aware that the relative intensities of conventional Taekwondo training activities could be potentially altered by varying work to rest ratios, number of actions, duration of practices, recovery periods, and the intensity (force) of executions. Furthermore, the duration spent on activities that were classified as eliciting hard relative exercise intensities were typically low over these sessions; therefore, coaches might be advised to consider spending greater time on these activities (e.g., specific sparring conditioning activities) or grouping several higher intensity activities together to ensure that the durations are sufficient to elicit cardiovascular adaptations. During sport-specific cardiovascular conditioning training sessions, it seems pertinent to suggest that athletes should practice sparring-related activities for a minimum of 20 minutes or accumulate these practices over a number of 10-minute bouts throughout the day, in accordance with the with current guidelines for improving and maintaining cardiovascular fitness. To further adhere to these general guidelines, competition-specific cardiovascular conditioning sessions should be conducted for a minimum of 3 days per week.

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