1.0 Introduction

Karate is a martial art that was introduced to mainland Japan in the early 20th Century. Now one of the most popular combat sports, Karate will be introduced into the Olympics for the first time at the Tokyo 2020 Games. The World Karate Federation (WKF) recognises 2 disciplines of Karate: Kata – the displaying of a sequence of movement patterns, and Kumite – actual sparring with an opponent. Within both disciplines, athletes are known as 'Karateka'. This chapter will focus on Karate Kumite, due to it being the more practiced form of Karate, which is also to be included within the next Olympics.

Within competitions, there are both Team and Individual matches – an athlete may participate in both within one competition. The team event for males consists of 5 competitors and two reserves, whereas the women's competition involves 3 competitors and 1 reserve. A typical competition schedule for both team and individuals involves a maximum of 5 rounds (including the final) within one day. At European and World competition-level, this can increase to 6 rounds within 1 day. The final would then be usually 1-2 days later. At the point of writing, the Olympic competition schedule has not been released. Bearing the number of bouts in mind, and also the 1 day period of competition, rest periods can be as little as 5 minutes between bouts, and as much as ~ 30 minutes. Therefore appropriate recovery interventions should be employed to maximise performance.

The competition matted area for Karate Kumite spans 8 meters x 8 meters, with a 1 meter border around the edge. Referees are seated at each corner, outside of the competition area, and a fifth judge stands centered between the two competitors, maintaining a 1 m distance to enable them to have a closer view and provide directions during the bout. Bouts last 3 minutes for males, and 2 minutes for females.

Competitors must wear a white karate gi without stripes, piping or personal embroidery to prevent injury or grip-points. The jacket, when tightened around the waist with the belt, must be of a minimum length that covers the hips, but must not be more than three-quarters thigh length. Female competitors may wear a plain white T-shirt beneath the Karate jacket. Jacket ties (which are inside the jacket to prevent it opening) must be tied. Jackets without ties may not be used.

For Senior Kumite Karateka, there are 5 weight categories each for open-age males and females (see Table 1).

<INSERT TABLE 1 HERE>

Table 1: Weight categories for international and Olympic Karate Kumite competitions

There are 3 primary means to scoring in Kumite, namely an 'Ippon' (3 pts), a 'Waza-Ari (2 pts), and a 'Yuko' – (1 pt) - with the winner being declared based on scoring the most points during the allotted time period. The bout can also be won if a Karateka builds an 8-point difference – for example 8-0, or 11-3. A score is awarded when a technique is performed according to the following criteria: good form, sporting attitude, vigorous application, awareness, good timing, and correct distance. An Ippon is awarded for Jodan kicks, and any scoring technique delivered on a thrown or fallen opponent. A Waza-Ari is awarded for Chudan kicks. A Yuko is awarded for a Chudan or Jodan Tsuki, and/or a Jodan or Chudan Uchi. Attacks are limited to the head, face, neck, abdomen, chest, back, and side.

This chapter will detail the movement-specific variables associated with Karate Kumite, as well as a physiological, biomechanical, and injury incidence analysis. An appropriate testing battery will be detailed, with the chapter cumulating in example programming for various levels of athletes.

2.0 Needs Analysis for Karate Kumite

2.1 Time-Motion Characteristics

The intermittent nature of Karate is well documented. Beneke et al. (2004) observed a 2:1 activity-to-break ratio among elite Karateka (see Table 2). Despite Beneke et al. (2004) conceding that this intermittence owes heavily to refereeing stoppages, Chaabene et al. (2014a) reported even higher intermittence among their high-level Karateka. Their activity-to-break ratio represented 1:1.5 – a figure echoed in Chaabene et al.'s (2014b) earlier research. Unlike the latter two studies, Beneke et al.'s (2004) findings were obtained through simulated bouts, which may explain the lower intermittence. In support of this, Chaabene et al. (2014a) also obtained data from simulated bouts (not included within Table 2), and observed an activity-to-break ratio of 1:1 – demonstrating lower intermittence to the 1:1.5 ratio observed during their official bouts.

<INSERT TABLE 2 HERE>

Table 2: Work-to-rest ratios in Karate Kumite

Regarding high intensity actions during Karate Kumite bouts, Table 2 demonstrates comparable findings. Individual actions were of low duration – all under 2 seconds for Chaabene et al. (2014b), and between 1 and 5s for Chaabene et al. (2014a). Iide et al. (2008) identified a total of 19.4 s (+/- 5.5 s) worth of technique combinations per 3 minute bout, with the longest enduring for 2.2 s, and the shortest, 0.2 s. It's worth noting that Koropanovski et al. (2008) observed 89% of points during World and European Championship final matches from 2002 to 2005 as being obtained through punches – and, with VencesBrito et al. (2011) stating that the Choku-Zuki punch occurs within 0.4 s, we can begin to understand why Karate bouts are of such an intermittent nature.

It is important to note that despite the 'decisive actions' in Karate being sporadic, Karateka are continuously working at high intensities during bouts. Sterkowicz and Franchini (2009) observed that a mere 11% of 'sequences of continuous work' during European Championship bouts lasted less than 7 seconds. In fact, 80% of sequences lasted 8 – 50 seconds, and 9.1% lasted 51 – 120 seconds. In light of this, it is important to examine further which energy systems are primarily relied upon during Karate Kumite.

2.2 Physiological Analysis

A 78% reliance on the aerobic energy system has been observed among elite Karateka - with just 16% reliance on the anaerobic-alactic system, and 6% on the ATP-PC system (Beneke et al. 2004). In support of this data, Doria et al. (2009) produced similar findings, with their internationally ranked Kumite Karateka demonstrating a 74% dependence on the aerobic system – considerably higher than their Kata counterparts in the same study (50%). The 16% anaerobic-alactic involvement (Beneke et al., 2004) nevertheless presents a noteworthy energy contribution, and can be attributed to the intermittent high-intensity actions mentioned earlier. The regular active-recovery periods that interrupt these high-intensity actions (Karateka are continually moving even when not in engaged in contact) can therefore account for the major contribution of the aerobic system in Karate Kumite. As Tomlin and Wenger (2001) note, better aerobic fitness can also enhance recovery from high-intensity intermittent training (due to enhanced post-exercise VO^2 and blood lactate removal).

Heart rate (HR) figures recorded during Kumite bouts reinforce the argument for the inclusion of an aerobic component within Karate S&C programmes. Chaabene et al. (2014b) observed their 14 national and international Karateka as spending 65% of their bouts over 90% of maximum HR. Imamura et al. (1996) and Chaabene et al. (2014a) submit higher figures - with mean HR's of 97% (+/- 4.2%) and 92% (of HR max) respectively. This

consistently high heart rate can be attributed to the 'bouncing' movement adopted by Karateka when not engaged in high intensity actions. Other combat sports – such as boxing and Muay Thai, tend to adopt a more flat-footed stance during their periods of active-recovery. Regarding beats per minute (bpm) Imamura et al. (1996), Iide et al. (2008), and Chaabene (2014a; 2014b) all observed mean HR's of between 160bpm (+/- 12.8) and 193bpm (+/- 8). In light of this data, strength and conditioning practitioners should consider aerobic conditioning interventions that are both intermittent, and consistently demanding on HR.

2.3 Biomechanical Analysis

Chaabene et al. (2014b) measured the movements of 14 elite Karateka during a national-level competition, and observed that 76% of 'techniques' were thrown with upper limbs. Of these upper limb movements, 74% were in the form of the Kizami-Zuki punch (Chaabene et al., 2014b). In line with this, Koropanovski et al. (2008) calculated that punches secured 89.09% of all points during 55 World Championship bouts - with kicks contributing just 8.36% of points. The predominance of upper limb use may therefore be attributed to their higher probability of obtaining points (compared to lower limbs). In further support of upper limb predominance, Jovanovic (1992) reported that the Kizami-Zuki takes just 110ms to perform. Having detailed the movement specific elements, the most common point scoring motions are explained in more detail.

During the execution of a Kizami-Zuki, power is primarily generated through a hip turn and arm extension (Arus, 2008). The hip turn relies heavily on the obliques - whilst the subsequent body drive principally engages the gluteus maximus, gastrocnemius, and quadriceps. The pronation of the palms during a Kizami-Zuki, ensure that the radius and ulna are mechanically firmer and less elastic (Link & Chou, 2011). VencesBrito et al. (2011)

analysed the kinematic and electromyographic (EMG) patterns of another commonly used punch – the Choku-Zuki. VencesBrito et al. (2011) in turn analysed the muscular activity of the muscles involved in the arm extension of the punch – measuring the EMG of 9 upper body muscles. The biceps brachii showed greater intensity of activation than the forearm muscles (pronator teres and brachioradialis).

<INSERT FIGURE 1 HERE>

Figure 1: Kizami –Zuki sequence

Although this breakdown allows for an analysis of which muscles are predominantly employed within key Karate movements, it is important for S&C practitioners to ensure that programming also includes sufficient coverage on the muscle groups used in the deceleration phase of movements. With techniques being thrown at such high speeds, both the agonist and antagonist muscles should be well conditioned, to minimise the risk of injury. Increasing antagonist muscle strength has also been suggested to increase movement speed, and accuracy of movement (Jaric et al., 1995). For example, within Karate, the hamstring muscles are employed to a greater extent than the quadriceps during the deceleration phase of a kick (Sbricolli et al., 2010). Although kicking techniques aren't used as frequently, they can prove the highest scoring techniques when executed successfully. The Mae-Geri (front kick) will therefore be analysed in more detail.

The Mae-Geri sequence requires participation of the torso, pelvis, knee, ankle, and foot (VencesBrito et al., 2014). During the hip rotation of the Mae-Geri, the foot accelerates at approximately 108 m/s^2, and drops to around 78 m/s^2 during the lower leg movement – reaching a final velocity of approximately 19 m/s (Gianino, 2010). Research into the kinematic and EMG characteristics of the Mae-Geri is scarce (VencesBrito et al., 2014) – as is data on flexibility and the required range of movements within Karate techniques in

general (Chaabene et al., 2012). The angles of the hip, knee, and ankle upon contact of a Mae-Geri have however been reported - and were 69° (+/- 26), 131° (+/- 8), and 98° (+/- 9) respectively (VencesBrito et al., 2014). Research on the time taken to execute the Mae-Geri is more readily available.

<INSERT FIGURE 2 HERE>

Figure 2: Mae-Geri sequence

Males (892ms +/- 103ms) have been reported to execute the Mae-Geri faster than females (1047ms +/- 157ms); however there was no link between speed and standing height (Sforza et al., 2002) – the fastest and the slowest males were the two shortest. Similar results were reported by Pozo et al. (2011), with their international level athletes completing the Mae-Geri faster (991ms +/- 93ms) than the national athletes (1139ms +/- 72ms). International athletes also demonstrated higher repeatability of execution time – although there was no difference in the impact force of kicks between internationals and nationals. This indicates that more emphasis should be placed on improving the speed of kicks (as opposed to force of the kick upon contact), in order for the strike to make contact before their opponent's does.

2.4 Incidence of Injury

Table 3 presents a summary of the data collected in major studies assessing the nature of injuries within Karate.

<INSERT TABLE 3 HERE>

Table 3: Review of literature on incidence of injury in Karate

2.4 Incidence of Injury

Injury rates within Karate are generally high, with between 0.24 and 0.31 injuries per bout reported in a number of studies (Macan et al., 2001; Tuominen, 1995; Milorad et al., 1983; McLatchie, 1976; Arriaza & Leyes, 2005; Johnannsen & Noerregaard, 1988). Only two studies within Table 3 (Critchley et al., 1999; Macan et al., 2006) reported figures of below 0.24 injuries per bout. Furthermore, within Kujala et al.'s (1995) multi-sport injury analysis, Karate fared higher (142 injuries per 1000 person years of exposure) than all other sports investigated, including soccer (89), ice-hockey (94), and Judo (117). Despite the relatively high injury rate, Karate is nevertheless seen as a relatively safe sport, due to the minor nature of these injuries.

The majority of research has identified the head and face as the most common location for injuries in Karate Kumite (Muller-Rath et al., 2000; Milorad et al., 1983; Critchley et al., 1999; McLatchie, 1976; Arriaza & Leyes, 2005; Macan et al., 2006). Most notably, Macan et al. (2001) and Tuominen (1995) reported that 97% and 95% of injuries recorded in their respective studies were to the head and face. Nevertheless, the majority of studies within Table 3 (of which include data on the nature of injuries) recognise bruising – minor in contrast to many sporting injuries, as the most frequent injury (Muller-Rath et al., 2000; Johnannsen & Noerregaard, 1988; Zetaruk et al., 2000a; Destombe et al., 2006; Arriaza & Leyes, 2005; Milorad et al., 1983). Strains, sprains, lacerations, and epistaxis were other commonly noted injuries.

Few studies analysed the direct contribution of punches and kicks to injuries – however, those that did (Muller-Rath et al., 2000; Milorad et al., 1983; Arriaza & Leyes, 2005) reported between 79% - 90% of injuries as being caused by punches. This high percentage of injuries that are caused by punches corresponds with Chaabene et al.'s (2014b) observation,

that 76% of ‘techniques’ are thrown with upper limbs. In summary, research shows that the majority of injuries suffered within Karate bouts are directly caused by opponent strikes, which limits the impact that strength and conditioning professionals can have on reducing injuries. Nevertheless, Zetaruk et al. (2000a) found that experience, training, and rank were a significant predictor of injury (risk of injury increased approximately three times with each additional year of experience). This can be attributed to the greater speed and force of techniques seen in more advanced Karateka. In order to maximise a Karateka’s prospect of avoiding an opponent’s strike, strength and conditioning professionals should ensure that programming includes sufficient content on power, speed and agility – through both plyometric and loaded strength-speed exercises.

<INSERT TABLE 4 HERE>

Table 4: Battery of fitness tests suitable for Karate athletes

4.0 Example strength & conditioning sessions for Karate

Based on the needs analysis conducted and a review of prevalent injuries, 2 appropriate strength and conditioning sessions have been outlined below (Table 4.1 and Table 4.2). The beginner and advanced sessions refer to strength and conditioning experience, not karate experience. The beginner sessions aims to get the athlete building a base of strength and power, through derivatives of the Olympic lifts and basic leg and back exercises. Exercises are performed at a low intensity, with a focus on developing technique. The advanced session assumes a sufficient base of technique, and therefore exercises are performed at a higher intensity, with lower volume. More complexes are included within the advanced session; with a focus on developing power in a lateral as well as frontal plane. As the sessions outlined below are power and strength sessions, no aerobic conditioning has been mentioned. As discussed within the needs analysis, aerobic conditioning for karate should be intermittent in nature, therefore a tabata format would be appropriate.

Table 4.1 Beginner power and strength session

<INSERT TABLE 4.1 HERE>

Table 4.2 Advanced power and strength session

<INSERT TABLE 4.2 HERE>

<INSERT FIGURE 3 HERE>

Figure 3: Single-arm ‘scissor’ landmine

4.3 Longitudinal programme design

The aim of this section is to present an example yearly schedule, and explain the role of the strength and conditioning coach within it. The programme (see table 5) is from an elite level athlete, however the principles still apply to the majority of karate athletes, due to the regular intervals of competitions during the competitive season.

The key difference between the karate programme featured in table 5 and other sporting macrocycles, is the structure of the competitive phase. Unlike most footballers or rugby players, Karateka are not competing weekly or bi-weekly during their competitive phases. During the competitive phases within karate there is generally 1 competition per month, which is normally contested over a weekend. An exception to this would be the World Championships, which generally last for 1 week.

The 2 sessions outlined above have been adapted from the specific preparatory phase. These can be characterised by a compound power and strength exercise (in this instance the power clean and back squat), followed by sport-specific strength and power exercises of a moderate intensity and volume. Due to the irregularity of competitions during the competitive phase, session content during this phase may not actually differ hugely from that which is featured in the specific preparatory phase – especially if 3 or so weeks out from a competition. As the competitive phase constitutes a significant part of the macrocycle (almost half a year in duration), it is important to strike the balance of not exhausting the athlete with volume - but also ensuring that gaps within the competition schedule are utilised appropriately, and not wasted. The greatest amount of training volume will be within the general preparatory phase, where less focus will be on the specificity of the exercise, and more on building an optimum base of fitness, strength, and if required – hypertrophy.

<INSERT TABLE 5 HERE>

Table 5: Periodisation of International English Karate athlete

5.0 Conclusion

Karate is a highly intermittent sport, with frequent high-intensity but low-duration actions. Even when not directly engaged in these 'actions', athletes are continuously working at a high intensity. This is reflected in research that has reported Karateka's mean heart rates to be above 90% of maximum (Imamura et al., 1996; Chaabene et al., 2014a). The regular active-recovery periods that interrupt the high-intensity actions can account for the 70%+ contribution of the aerobic system reported by Beneke et al. (2004) and Doria et al. (2009).

76% of techniques within karate are thrown with upper limbs (Chaabene et al., 2014b). This is reflected in Koropanovski et al.'s (2008) calculations - that punches secured 89.09% of all points during 55 World Championship bouts. The predominance of upper limb use may be attributed to the higher probability of punches obtaining points, and also the speed at which punches can be executed. The Kizami-Zuki punch can be completed within 110ms (Jovanovic, 1992, cited in Chaabene, 2014a), whereas the Mae Geri front kick has been reported to take between 721ms and 1308ms to execute (Sforza et al., 2002).

Injury rates within Karate are generally high - however due to the minor nature of these injuries, Karate is seen as a relatively safe sport. Bruises are widely reported as the most common injury (Muller-Rath et al., 2000; Johnannsen & Noerregaard, 1988; Zetaruk et al., 2000a; Destombe et al., 2006; Arriaza & Leyes, 2005; Milorad et al., 1983), with the head and face recognised as the most common location for injuries (Muller-Rath et al., 2000; Milorad et al., 1983; Critchley et al., 1999; McLatchie, 1976; Arriaza & Leyes, 2005; Macan et al., 2006). Higher injury rates have been associated with more experienced Karateka (Zetaruk et al., 2000a), probably due to the greater speed and force of techniques seen in more advanced Karateka.

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