WHAT MAKES A SUCCESSFUL SPARING TAEKWONDO ATHLETE?

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DEDICATION

I would like to dedicate this portfolio to my loving wife, Insook, my son Jesse, my father and mother for all they have poured into my life and to my Lord Jesus for his unfailing love and grace.

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TABLE OF CONTENTS

GLOSSARY

Adverse Events: are unwanted and usually harmful outcomes.

Athlete Exposure (A-E): A unit of susceptibility to injury, which is defined as one athlete participating in one game or practice, in which he/she is exposed to the possibility of athletic injury.

Age in sport: number of years of experience in sport.

Body Mass (BM): or human body weight is used colloquially and in the biological and medical sciences to refer to a person's mass or weight, measured in kilogram (kg).

Body Mass Index (BMI): a measure of body fat calculated using weight (kg) and height (m); BMI=weight /height^2 (kg/m^2).

Confidence interval (CI): Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter.

Gam-Jeom (GJ): a deduction penalty and is counted as a deduction of one point for the participant who used illegal moves or behaviours.

Generalized Estimating Equations (GEE): is used to estimate the parameters of a generalized linear model with a possible unknown correlation between outcomes. Parameter estimates from the GEE are consistent even when the covariance structure is misspecified, under mild regularity conditions.

Grappling martial arts: refers to techniques, manoeuvres, and counters applied to an opponent in order to gain a physical advantage, such as improving relative position, escaping, submitting, or injury to the opponent but does not include striking. Judo, wrestling, and Aikido are grappling martial arts.

Injury: For the purposes of these studies, an athlete was considered injured if any of the following conditions applied (Lindenfeild et al. 1994): 1) any circumstance that forced the athlete to leave the competition; 2) any circumstance for which the referee or athlete had to stop competition; 3) any circumstance for which the athlete requested medical attention. In other words, the definition included so-called time-loss injuries (stoppage of a bout) as used in the NCAA Injury Surveillance System.

Injuries per 1,000 athlete-exposures: Injury rates were calculated from matches fought using the basic rate formula: (# injuries / # athlete-exposures) x 1,000 = # injuries per 1,000 athlete-exposures (A-E).

Injury Report Form (IRF): See Appendix 4

Joint dysfunction: Haldeman (1992) defines joint dysfunction quoting Drum (1973) as, "Joint mechanics showing area disturbances of function without structural change; subtle joint dysfunctions affecting quality and range of joint motion. They are diagnosed with the aid of motion palpation, as well as stress and motion radiography investigation" [p. 623]. Greenman (1996) states: "Joint dysfunction is characterized by findings of misalignment, relative fixation, loss of normal range-of-motion and end-play, tenderness, and tissue texture abnormality".

Kyong-Go (KG): a warning penalty; two KG's in a match are counted as a deduction of one point for the athlete.

Lean body mass: is a component of body composition, calculated by subtracting body fat weight from total body weight.

Odds Ratio (OR): is a measure of association between an exposure and an outcome. The OR represents the **odds** that an outcome will occur given a particular exposure, compared to the **odds** of the outcome occurring in the absence of that exposure.

PSS: Electronic Protector and Scoring System

Revised Injury Report Form (rIRF): See Appendix 5

Striking martial arts: refers to martial arts that utilize striking techniques to score a point such as taekwondo, karate and Kungfu.

TAEKWONDO: TKD, Tae Kwon Do is Korean striking martial art, which uses mainly kicks to score a point.

Weight cycling/cutting: The cyclical loss and gain of Body mass.

Rapid weight loss (RWL): refers to losing weight in a short period of time usually less than a week.

Rapid Weight Gain (RWG): refers to weight gained between official weighing and the time of

competition.

World Taekwondo Federation (WTF): is the international federation governing the sport of taekwondo and is a member of the Association of Summer Olympic International Federations.

ABSTRACT

Taekwondo (TKD), a Korean striking martial art, has become one of the most popular martial arts since its inclusion in 2000 Olympic Games. Having practiced TKD as an athlete and provided care as a health professional for decades, I investigated a series of features of the Olympic TKD athlete including: profile, injury rate and distribution, weight cycling/cutting and each of their relationships to success in terms of gaining a medal. My studies (Kazemi et al. 2006; Kazemi, Perri and Casella, 2009; Kazemi et al. 2010; Kazemi et al. 2013; Kazemi et al. 2014; Kazemi et al. 2015; Kazemi and Pieter 2004; Pieter and Kazemi 2007; Kazemi, Chudolinski et al. 2009; Kazemi 2012; Kazemi et al. 2005; Kazemi and Shearer 2007; and Kazemi et al. 2011) have demonstrated that an athlete who avoids injury during competition (especially severe injury), practices systematic and gradual weight management and utilizes a more aggressive strategy with no fear of receiving Kyong-Gos, whilst avoiding receiving Gam-Jeoms is more likely to win. These investigations were published and presented at various seminars around the world. This portfolio depicts my contributions to these areas of knowledge as well as further critical analysis of my previous works giving birth to new concepts such as utilization of height categories instead of weight categories to eliminate the ill-effects of weight cutting; sparring Injury Report Form; and effect of rule changes on profile and injuries to name a few. Conducting this thesis has helped me to reflect on the shortcomings of my previous investigations and realize the future directions of research in these areas.

INTRODUCTION

Taekwondo (TKD), a Korean striking martial art, gained full-medal status at 2000 Olympics (World taekwondo Federation, 2013). As such, understanding the injuries, potentially harmful practices (such as weight cycling) and characteristics associated with becoming a successful athlete, are important to health practitioners, coaches and athletes alike.

My contribution to the understanding of the above issues relating to TKD can be apportioned into three distinct areas:

1. Determination of the elite Olympic TKD Athlete's Profile (Kazemi et al. 2006; 2010; 2013; 2014; 2015; and Kazemi, Perri and Casella 2009)

2. Determination of the injury rate and its distribution (Kazemi and Pieter 2004; Pieter and Kazemi 2007; Kazemi, Chudolinski, et al. 2009; and Kazemi 2012)

3. Determination of the effect of weight cycling/cutting on performance in TKD. (Kazemi et al. 2005 and 2011; Kazemi and Shearer 2007)

As primary author in the above studies, I was involved in all facets of these studies including development of the hypothesis and study design, compilation of the research literature, data collection, and manuscript development. In addition, I submitted the papers to appropriate journals and responded to the reviewers. The Research Ethical Board of Canadian Memorial Chiropractic College (CMCC) approved all my research studies.

Proposal

For the purpose of fulfilling the requirements for the PhD by Portfolio, I have undertaken a reflective critique of the three themes of my contribution to the knowledge in TKD and martial arts. As part of this process, I updated and improved the literature review in these areas and compared and considered implications in other similar disciplines. Furthermore, I have outlined future research and recommendations that could be derived from my work.

In the following pages I have attempted to explain the historical events and rationale for each study followed by a summary of each study in each theme to give a background context regarding my contribution to these areas. As each study was performed, gaps in knowledge were identified and used to formulate the future research questions. Where it was possible, additional studies were performed based on improving the criteria following analysis of the previously gathered data. As a consequence of this reflective exercise, I have also critiqued the series of studies as a whole and as a result have identified further refinements and research. Although the work was performed in a different sequence to that

presented in this thesis, this approach has been taken for the benefit of the reader, as it is the author's considered opinion that the order of presentation in this thesis is easier to follow and enables the subject matter presented to be understood by a wider audience. As a further indicator of impact, a section (appendix 2) has been included which lists the publications and their current number of citations in the literature.

1. PROFILE OF THE ELITE OLYMPIC TAEKWONDO ATHLETE

BACKGROUND

I started practicing TKD at the age of fifteen, obtained my black belt at age of 23 and continue to practice and compete today. In 1999 I travelled with the Canadian team, as the team doctor, to World championships and then regional 2000 Olympics qualifying championships; an event in which one of my athletes qualified to compete at the first ever Olympics to include TKD - the 2000 summer Olympic games in Sydney. There were a number of myths among coaches and athletes with regards to characteristics of a successful TKD athlete; height (the taller athlete), age (younger athlete), lower BMI and use of more offensive techniques were all associated with having a better chance to medal. At the time, there was little in the literature to address these statements. During the 2000 Olympics, my athlete won the bronze medal, which motivated me to consider whether it was possible to predict the winner based on their profile. Previous studies had investigated relationships between performance and anthropometric and physical characteristics of TKD players (Gao 2001; Gao et al. 1998; Heller et al. 1998; Markovic et al. 2005; Melhim 2001; Yujin and Zeng 1999; Zhao et al. 1999). To my knowledge, no one had used 'medalling' at an Olympic Game as a measure of success, even though everyone from coaches to athletes consider this to be the ultimate success. Consequently I decided to investigate these urban myths using the most elite TKD athletes.

As there had been little research conducted in the area of performance in the martial arts and its relation to anthropometric variables such as body weight and height, the first in this series of studies examined the profile of champions (Gold, Silver and Bronze medallists) at the inaugural Olympics for TKD (Kazemi et al. 2006) and each subsequent Olympics until 2012 (Kazemi, Perri and Casella 2009; Kazemi et al. 2010; Kazemi et al. 2014). Briefly, these studies did not find any statistical difference in average age, BMI, height or weight between winners and non-winners. Athletes scored mainly by offensive kicks and winners used more punches to score. Winners received significantly more Kyong-Go (KG, a warning penalty) than non-winners (Kazemi, Perri and Casella 2009; Kazemi et al. 2010; Kazemi et al. 2014). There had been numerous rule changes during this 12-year period that were fundamental to how the athletes score a point or receive warnings, which affected the outcome of the match.

One of the limitations of my four studies in this area (Kazemi el al. 2006, 2009, 2010, 2014) was small sample size and its possible contribution (under-powering) to not having any statistically significant outcomes. As such, this thesis has given me the opportunity to consider the data longitudinally across all four games to determine whether there were any significant contributors to success that could be identified, utilizing the much larger sample size (Kazemi et al. 2015). I will be discussing Kazemi et al. (2015) in the rest of this chapter.

METHODS AND PROCEDURES

The data set used in Kazemi el al. (2015) was obtained from the official Olympic websites (Sydney 2000, Athens 2004, Beijing 2008, London 2012 and World taekwondo Federation (WTF)(2015). The WTF provided the weight of each athlete at weigh-in for all Olympic athletes. Limitations of this method include entry errors and missing data. The information obtained from these websites includes: gender, weight and weight category, height, date of birth, country, round report, points obtained, warnings (KG), deduction points (GJ), and techniques used to score (defensive kicks, offensive kicks, defensive punches and offensive punches).

As a result of change to the scoring system across the Olympic events, all variables related to technique were converted into percentages to ensure consistency. Calculations developed for these percentages are shown below:

1. Percentage of offensive points = $\frac{\text{Offensive points}}{\text{Offensive + defensive points}}$

2. Percentage of kick points that were offensive = $\frac{\text{Offensive kicks}}{\text{Total offensive points}}$

The population of this study was 482; the independent variables (age, gender, BMI, technique used to score, deductions from match and warnings per match) described in the data set were used to determine the outcome measures of winners versus non-winners. This outcome measure included those participants obtaining a medal, regardless of level of achievement (gold, silver or bronze).

The data obtained were then entered into an excel spread sheet and transferred to a STATA version 10.0 file. A LOGIT analysis was performed using the following 6 independent variables: age, gender, BMI, techniques used to score (offensive kicks and punches), deductions (GJ & KG) per match and warning penalties (KG) per match.

To minimize error in the data entry, two secondary investigators independently input data into a Microsoft Excel spread sheet (version 2011 of Excel). Once verified, the data were compared for differences. Athletes who participated in more than one of the Olympics from 2000-2012 were accounted for by assigning them the same subject number to prevent overlap and double entry of their data.

RESULTS

Table 1.1 outlines the demographics for TKD participants included in the four Olympic Games included in this study. It is apparent from the data presented that there were no statistical differences between the winners and non-winners in each category.

Table 1.1 Mean descriptive characteristics of male and female taekwondo medalist versus non-medalist athletes who competed in the 2000 through 2012 Olympic Games. Data are combined over the four Olympic Games.

Characteristics	Male winners (n=56)	Male non-winners (n=190)	Female winners (n=56)	Female non-winners (n=180)
Age (years)	23.88 (5.25)	25.14 (4.02)	23.41 (3.27)	23.56 (4.32)
Height (m)	1.84 (0.09)	1.81 (0.08)	1.70 (0.07)	1.70 (0.07)
Weight (kg)	74.77 (14.06)	73.72 (13.20)	60.44 (9.16)	60.94 (9.64)
BMI (kg/m^2)	21.93 (2.57)	22.49 (2.70)	20.75 (2.36)	20.94 (2.24)

Table 1.1 legend: total number of subjects entered: n=482. Data presented as Mean±1SD; the following abbreviations were used: BMI, Body Mass Index; m, metres; kg, kilograms;

Logistic regression analysis revealed no statistical relationship between winning and age, BMI, weight or height. By adding in the variable "KG's per match" along with the three core variables there was a significant difference (p= 0.0013: Kazemi et al. 2015). KG data shows highly significant correlation to medalling (p=0.0078 and 0.027 for percentage offensive points or percentage of offensive kicks respectively: Table 1.2).

Table 1.2 Logistic regression analysis of different combinations of variables for medalist versus non-medalist taekwondo competitors. Data are combined over the 2000 through 2012 Olympic Games.

Outcome	Odds Ratio	[95% Conf. Interval]		Std. Err	P value
Age	0.97	0.92	1.02	0.03	0.24
Gender	0.99	0.63	1.56	0.23	0.97
BMI	0.96	0.89	1.04	0.04	0.38
Age	0.96	0.91	1.02	0.03	0.19
Gender	0.85	0.53	1.38	0.24	0.52
BMI	0.99	0.91	1.08	0.04	0.87
Ded. Per match	1.00	0.43	2.33	0.43	1.00
KG per match	1.40	0.91	2.14	0.22	0.12
Age	0.96	0.91	1.02	0.03	0.19
Gender	0.85	0.53	1.38	0.24	0.52
BMI	0.99	0.91	1.08	0.04	0.87
KG per match*	1.40	1.14	1.71	0.10	**0.001**
Age	0.96	0.91	1.02	0.03	0.19
Gender	0.80	0.49	1.30	0.25	0.36
BMI	0.98	0.90	1.07	0.04	0.72
KG per match*	1.34	1.08	1.65	0.11	**0.01**
% Off. Points	0.59	0.29	1.17	0.35	0.13
Age	0.98	0.92	1.03	0.03	0.41
Gender	0.87	0.53	1.44	0.25	0.59
BMI	0.97	0.87	1.07	0.05	0.50
KG per match*	1.29	1.03	1.60	0.11	**0.03**
% Off. Kicks	0.53	0.001	331.01	3.29	0.85

Table 1.2 legend: * Indicates statistical significance with a probability (p) $\leq$ 0.05. This table displays data for the following: age, gender, BMI deductions per match (Ded. Per match), (Kyong-Go) KG per match % offensive points (% Off. Points) and % offensive kicks (% Off Kicks). The actual statistical outcome of comparison between winners and non-winners is shown in the p value column: those achieving significance are presented in bold text (Kazemi et al. 2015).

Tables 1.3-1.5a,b demonstrate the demographics profiles, techniques, warnings and penalties of TKD athletes participated in Olympic Games 2000-2012.

Table 1.3. Mean descriptive characteristics of male and female taekwondo medalist versus non-medalist competitors who participated in the 2000, 2004, 2008, and 2012 Olympic Games.

	Males		**Females**		
Characteristics	**Winners**	**Others**	**Winners**	**Others**	**Total Athletes**
2000	***(n=12)***	***(n=43)***	***(n=12)***	***(n=36***	***(n=103)***
Age (years)	24.4 ± 3.3	25.2 ± 4.3	23.1 ± 3.9	24.9 ± 4.7	
Height (m)	1.8 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	
Weight (kg)	73.4 ± 12.1	73.7 ± 14.3	60.3 ± 9.1	61.3 ± 10.9	
BMI	21.9 ± 2.4	22.8 ± 3.3	20.8 ± 2.3	21.3 ± 2.7	
2004	***(n=12)***	***(n=52)***	***(n=12)***	***(n=48)***	***(n=124)***
Age (years)	26.1 ± 4.6	26.0 ± 4.3	24.3 ± 4.9	24.5 ± 4.7	
Height (m)	1.8 ± 0.11	1.8 ± 0.08	1.7 ± 0.1	1.7 ± 0.1	
Weight (kg)	75.8 ± 16.1	74.1 ± 13.0	61.3 ± 10.5	60.9 ± 9.4	
BMI	22.4 ± 2.3	22.5 ± 2.5	20.4 ± 2.5	21.1 ± 2.2	
2008	***(n=16)***	***(n=48)***	***(n=16)***	***(n=48)***	***(n=128)***
Age (years)	25.0 ± 3.5	24.8 ± 4.3	22.8 ± 2.8	22.9 ± 4.5	
Height (m)	1.8 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	
Weight (kg)	74.9 ± 14.7	73.1 ± 12.4	59.9 ± 9.4	60.7 ± 8.7	
BMI	22.0 ± 2.6	22.5 ± 2.4	21.0 ± 2.4	20.7 ± 1.9	
2012	***(n=16)***	***(n=48)***	***(n=16)***	***(n=48)***	***(n=128)***
Age (years)	24.1 ± 3.1	25.8 ± 4.0	23.9 ± 3.0	23.5 ± 4.1	
Height (m)	1.9 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	
Weight (kg)	75.0 ± 14.6	73.8 ± 13.7	60.7 ± 8.9	60.8 ± 10.0	
BMI	21.6 ± 3.0	22.3 ± 2.8	20.7 ± 2.4	20.8 ± 2.2	

Table 1.3 legend: data presented as Mean ±1SD; BMI, Body Mass Index; m, metres; kg, kilograms (Kazemi et al. 2014).

Table 1. 4. Mean descriptive characteristics of male and female taekwondo athletes by body mass competition category, who participated in the 2000, 2004, 2008, and 2012 Olympic Games.

Weight Category	Average age (yrs.)	Average height (m)	Average weight (kg)	Average BMI
2000 *Males*				
<58kg	24.3	1.7	57.6	19.3
<68kg	23.4	1.8	67.3	21.7
<80kg	26.1	1.8	78.5	23.5
>80kg	26.2	1.9	92.0	25.9
Females				
<49kg	22.2	1.6	48.5	18.2
<57kg	23.6	1.7	56.3	20.8
<67kg	26.7	1.7	64.6	21.7
>67kg	24.8	1.8	74.5	23.9
2004 *Males*				
<58kg	22.8	1.7	57.7	19.7
<68kg	24.7	1.8	67.3	21.0
<80kg	25.9	1.8	80.7	23.9
>80kg	30.6	1.9	91.1	25.4
Females				
<49kg	22.3	1.6	48.6	18.5
<57kg	23.3	1.7	56.8	19.8
<67kg	23.5	1.7	65.9	22.1
>67kg	28.5	1.8	72.7	23.3
2008 *Males*				
<58kg	24.2	1.7	58.2	19.7
<68kg	22.5	1.8	68.7	21.9
<80kg	25.8	1.9	79.4	23.3
>80kg	27.1	1.9	91.4	25.2
Females				
<49kg	20.7	1.6	49.1	18.4
<57kg	23.1	1.7	56.3	19.9
<67kg	24.6	1.7	65.3	21.9
>67kg	23.2	1.8	70.9	22.7
2012 *Males*				
<58kg	23.3	1.8	57.6	18.9
<68kg	25.3	1.8	67.6	20.9
<80kg	26.1	1.9	78.5	22.8
>80kg	26.9	1.9	93.0	25.7
Females				
<49kg	23.8	1.6	48.6	18.2
<57kg	23.2	1.7	56.5	20.2
<67kg	23.2	1.7	65.2	21.6
>67kg	24.1	1.8	72.9	23.0

Table 1.4 legend: data presented as Mean±SD. The following abbreviations were used: yrs, Years; BMI, Body Mass Index; m, metres; kg, kilograms; data published in Kazemi et al. (2014).

Table 1.5a. Total points earned and penalties awarded, by category, to male taekwondo athletes during the 2000, 2004, 2008, and 2012 Olympic Games.

Weight Category of Males	KG warning penalty	Gam-Jeon deduction penalty	Offensive kick 1pt	Offensive kick 2pt	Offensive kick 3pt	Offensive kick 4pt	Defensive kick 1pt	Defensive kick 2pt	Defensive kick 3 pt	Defensive kick 4pt	Offensive punch	Defensive punch	Knock down
2000													
<58kg	-	-	69	-	-	-	89	-	-	-	2		-
<68kg	-	-	142	-	-	-	92	-	-	-	2		-
<80kg	-	-	115	-	-	-	39	-	-	-	0		-
>80kg	-	-	111	-	-	-	76				0		-
Total	-	-	**437**	-	-	-	**296**	-	-	-	**4**		-
2004													
<58kg	75	29	104	14	-	-	66	-	-	-	0	0	1
<68kg	85	32	189	7	-	-	111	-	-	-	0	0	1
<80kg	77	30	216	10	-	-	119	-	-	-	0	0	1
>80kg	61	22	117	10			54				0	0	1
Total	**298**	**113**	**626**	**41**	**-**	**-**	**351**	**-**	**-**	**-**	**0**	**0**	**4**
2008													
<58kg	44	12	33	5	-	-	42	0	-	-	0	1	0
<68kg	40	11	39	2	-	-	49	1	-	-	0	0	0
<80kg	37	10	40	4	-	-	55	3	-	-	0	1	1
>80kg	43	12	50	6	-	-	63	1	-	-	0	0	0
Total	**164**	**45**	**162**	**17**	**-**	**-**	**209**	**5**	**-**	**-**	**0**	**2**	**1**
2012													
<58kg	70	2	78	2	13	0	36	3	7	2	2	3	0
<68kg	89	2	54	6	8	1	29	5	10	2	2	2	0
<80kg	58	3	51	1	12	0	26	1	6	2	0	3	0
>80kg	64	2	39	2	16	1	23	5	7	1	0	7	0
Total	**281**	**9**	**222**	**11**	**49**	**2**	**114**	**14**	**30**	**7**	**4**	**15**	**0**

Table 1.5 legend:"-" Represent scoring that was not used in the respective year. Please note in 2000, punches were not divided into offensive and defensive punches (Kazemi et al. 2014). The following abbreviations were used: KG, Kyung-Go; kg, kilograms; pt, point/s.

Table 1.5b. Total points earned and penalties awarded, by category, to female taekwondo athletes during the 2000, 2004, 2008, and 2012 Olympic Games.

Weight Category of Males	KG warning penalty	Gam-Jeon deduction penalty	Offensive kick 1pt	Offensive kick 2pt	Offensive kick 3pt	Offensive kick 4pt	Defensive kick 1pt	Defensive kick 2pt	Defensive kick 3 pt	Defensive kick 4pt	Offensive punch	Defensive punch	Knock down
2000													
<49kg	-	-	66	-	-	-	68	-	-	-	1		-
<57kg	-	-	134	-	-	-	96	-	-	-	0		-
<67kg	-	-	91	-	-	-	118	-	-	-	0		-
>67kg	-	-	152	-	-	-	110	-	-	-	0		-
Total	-	-	**443**	-	-	-	**392**	-	-	-	**1**		-
2004													
<49kg	32	9	67	5	-	-	24	-	-	-	0	0	0
<57kg	42	15	85	13	-	-	57	-	-	-	0	0	0
<67kg	51	16	101	3	-	-	80	-	-	-	0	0	0
>67kg	49	17	139	3	-	-	107	-	-	-	0	0	0
Total	**174**	**56**	**392**	**24**	**-**	**-**	**268**	**-**	**-**	**-**	**0**	**0**	**0**
2008													
<49kg	38	11	28	5	-	-	34	4	-	-	0	0	0
<57kg	41	10	24	4	-	-	42	5	-	-	0	0	0
<67kg	28	7	33	2	-	-	40	2	-	-	0	0	0
>67kg	34	9	48	2	-	-	65	1	-	-	0	0	0
Total	**141**	**37**	**133**	**13**	**-**	**-**	**181**	**12**	**-**	**-**	**0**	**0**	**0**
2012													
<49kg	57	0	36	3	30	3	15	3	9	0	2	10	0
<57kg	58	1	48	4	18	0	44	7	20	1	0	3	0
<67kg	43	1	48	3	20	1	25	2	8	1	1	2	0
>67kg	58	1	87	6	22	1	33	3	10	5	2	15	0
Total	**216**	**3**	**219**	**16**	**90**	**5**	**117**	**15**	**47**	**7**	**5**	**30**	**0**

Table 1.5 legend:"-" Represent scoring that was not used in the respective year. Please note in 2000, punches were not divided into offensive and defensive punches (Kazemi et al. 2014). The following abbreviations were used: KG, Kyung-Go; kg, kilograms; pt, point/s.

Updated Literature review

In addition to the literature review conducted at the time of the studies (Kazemi, Perri and Casella 2009 and Kazemi et al. 2006; 2010), the review of the literature from Kazemi et al. (2014) has been updated using the STARLITE mnemonic (sampling strategy, type of study, approaches, range of years, limits, inclusion and exclusions, terms used, electronic sources: Booth 2006). PubMed/MEDLINE, CINAHL, SPORTDiscus, and Rehabilitation & Sports Medicine Source databases were searched using Boolean operators of and, or and not, wild card of *, plus a combination of terms, "Tae Kwon Do or taekwondo AND performance or winning AND profile". There was no limit to range of years. Studies were included if they were currently published, peer reviewed, randomized controlled trials (RCTs), reviews of literature or cohort studies written in the English language. Excluded from this review of the literature were case studies, studies pertaining to any journal not published in the English language.

This search yielded 12 citations in addition to what were already retrieved at the time of each study. To include further papers the following search was run using, "Tae Kwon Do or taekwondo AND profile" which yielded 29 citations. Three relevant studies were found, in addition to my studies (Albuquerque et al. 2012; Cular et al. 2013; Kwok 2012) (Table 1.6). In addition, for comparison reasons other relevant papers on other sports were also included (Andreato et al. 2017; Carvajal et al. 2012; Chaabène et al. 2012: Etter et al. 2013; James et al. 2016; Trewin et al. 2004; Zi-Hong et al. 2013).

Table 1.6. Profiles of successful elite athletes, as reported in the literature.

Study	Design	Sample origin and size presented in the study (n)	Number of competitions	Level of competition	Reported findings
Albuquerque et al. (2012)	Retrospective	291 male and female Olympic TKD athletes	3	Olympic Games (2000, 2004, 2008)	There were no discernable effects of relative age on Olympic TKD athletes. Relative age effects refer to the effects of age differences among individuals who have been grouped together for a performance activity and they have been viewed as discriminatory against athletes born near the end of the year.
Andreato et al. (2017)	Systematic review of literature	1496 Brazilian jiu-jitsu athletes	-	National and international	They reported that body fat was generally low for these athletes and the mesomorphic component was predominant. The different studies showed VO_{2max} values between 42 and 52 mL/kg/min, and it seemed that aerobic fitness did not discriminate among Brazilian jiu-jitsu athletes of different competitive levels. There was a lack of scientific studies that had investigated anaerobic responses both in lower and upper limbs. Maximal dynamic, isometric and endurance strength could be associated with sporting success in Brazilian jiu-jitsu athletes. Although decisive actions during Brazilian jiu-jitsu matches were mainly dependent on muscular power, more specific studies are necessary to describe it. Studies involving the female sex should be conducted.

Bridge et al. (2014)	Review of literature	Male and female TKD athletes	-	International	International TKD athletes possessed low levels of body fat and a somatotype that characterises a blend of moderate musculoskeletal tissue and relative body linearity. While there was some variation in the maximum oxygen uptake of TKD athletes, moderate to high levels of cardio-respiratory fitness were necessary to support the metabolic demands of fighting and to facilitate recovery between consecutive matches. TKD athletes demonstrated high peak anaerobic power characteristics of the lower limbs and this attribute appears to be conducive to achieving success in international competition. The ability to generate and sustain power output using both concentric and 'stretch-shortening cycle' muscle actions of the lower limbs might be important to support the technical and tactical actions in combat. TKD competitors also displayed moderate to high maximum dynamic strength characteristics of the lower and upper extremities, and moderate endurance properties of the trunk and hip flexor musculature. The dynamic nature of the technical and tactical actions in the sport demanded high flexibility of the lower limbs.
Carvajal et al. (2012)	Observational	41 Cuban Olympic Women volleyball athletes	3	Olympic Games (1992, 1996 and 2000)	The kinanthropometric profile of Cuban women Olympic volleyball champions was defined by considerable muscular-skeletal development, with a predominantly mesomorphic somatotype and low endomorphy with varied height and body composition significantly by playing position.

Chaabène et al. (2012)	Review of literature	Karate Athletes	-	National and international	They reported that karate's top-level performers required a high fitness level. Top-level male karate athletes were typified by low body fat and mesomorphic-ectomorphic somatotype characteristics. Studies dealing with body composition and somatotype of females were scarce. Aerobic capacity reported to play a major role in karate performance. Concerning anaerobic performance, there was a difference in maximal power explored by the force-velocity test between national and international level karatekas (karate practitioners) but, for the maximum accumulated oxygen deficit test there was no difference between them. Muscle explosive power plays a vital role in a karateka's capacity for high-level performance. Karate's decisive actions were essentially dependent on muscle explosive power in both the upper and lower limbs. . A significant difference in the choice reaction time between high-level and novice karatekas existed.
Cular et al. (2013)	Survey/ Questionnaire	242 WTF instructors	-	-	These authors reported that top instructors assigned the highest portion of impact on success to the athletes' motor and functional skills. The top instructors assigned the highest portion of impact on success to the motor and functional skills (MOTFS) variable: WTF-SPB=29.1, ITF SPB=29.2, WTF-THN=35.0, ITF-THN=32.0). Furthermore, all instructors generally agreed with the claim that technical and tactical competence (from 20.45% to 26.9%), as well as the psychological profile of an athlete

					(from 15.4% to 23.7%), were important for all disciplines of both systems. They ranked the former as the second and the latter as the third most important factor for achieving good results in taekwondo. The instructors believed that least impact across all disciplines in relation to all 5 offered factors could be assigned to athletic intelligence (from 10.4% to 15.0%) and morphological characteristics (from 11.6% to 15.4%). Statistically significant differences in opinions of instructors of different styles and disciplines were not recorded in any of the analysed variables. The only exception was the psychological profile of an athlete variable, which WTF instructors of sparring (AM= 23.7%), on a significance level of P<0.01, evaluated as having a statistically significantly higher impact on success in taekwondo than WTF instructors of technical discipline of patterns (15.4%).
Etter et al. (2013)	Retrospective	7,939 (1,666 females and 6,273 males) Triathlon athletes	-	2000-2010 Olympic distance 'Zürich Triathlon'	These authors found that for both elite and age group athletes, the gender difference in cycling time was significantly (P <0.001) lower than for swimming and running. The gender difference in overall Olympic distance triathlon performance increased after the age of 35 years, which appeared earlier compared to long distance triathlon as suggested by previous studies.

James et al. (2016)	Review of literature	Mixed martial arts, boxing, Brazilian jiu-jitsu, judo, karate, kickboxing, Muay Thai and wrestling male, adult (aged 17-40 years), able-bodied athletes of differing competition levels The search history spanned from the earliest record until September 2015.	-	National and international	These authors reported that there appeared to be differing physiological profiles between more successful grappling and striking combat sport athletes. This was represented by high-force demands of grappling sports causing an upward shift of the entire force-velocity relationship driven by an increase in maximal strength. In comparison, smaller increases in maximal force production with more notable enhancements in lighter load, higher velocity actions might better identify superior performance in striking sports. Anaerobic capabilities largely distinguished higher- from lower-level combat sport athletes. In particular, longer-term anaerobic efforts seemed to define successful grappling-based athletes, while superior competitors in striking sports tended to show dominance in shorter-term measures when compared with their lower-level counterparts. Given the demand for both forms of combat in MMA, a spectrum of physiological markers might characterize higher-level competitors. Furthermore, the performance profile of successful MMA athletes might differ based on combat sport history or competition strategy.
Kazemi et al. (2014)	Retrospective	128, male and female TKD Olympic athletes	1	Olympic Games 2012	Male winners were slightly younger, taller, with a slightly lower BMI versus non-winners. Female winners were slightly older, taller, with a slightly lower BMI versus non-winners. However, these were not statistically significant. They found that more kicks per match were associated with winning in males but less so in females.

					Winners scored twice as often as non-winners using punches. In terms of strategic differences between winners and non-winners, there were no statistical significances found within the data. In terms of physiological differences between winners and non-winners, there were no statistical significances found, even in comparison to previous years. Comparisons between the previous competitions and the results of the OR showed winning was best achieved through an offensive strategy (via the use of kicks and the increased frequency of punches) and should be considered by coaches for future competitions.
Kazemi, Perri, and Casella (2009)	Retrospective	124, male and female TKD Olympic athletes	1	Olympic Games 2004	Winners were slightly taller and had a slightly lower BMI than non-winners; however, these were not statistically significant. Overall, kicking was the only technique used to score points during competition. Specifically, for both male and females one point offensive kicks were used to score the most points, followed by defensive kicks, and offensive two-point kicks. There was a significant increase in the number of Kyong-Go (half point deduction warning) and Gam-Jeom (one point deduction warning) in the 2004 Olympic Games compared to that in 2000 Olympic Games, which might suggest more aggressive fighting style in the 2004 Olympic Games. Women were eight times more likely to win by superiority than men.

Kazemi, et al. (2010)	Retrospective	128, male and female TKD Olympic athletes	1	Olympic Games 2008	Male winners tended to be slightly older, taller, with lower BMIs versus non-winners. Female winners were slightly younger, shorter, with greater BMI's versus non-winners. However, these were not statistically significant. A higher proportion of scores by defensive kicks was found among male competitors in 2008 (0.539, n = 388) versus 2004 (0.345, n = 1018) ($p < 0.0001$). For women the result was similar in 2008 (prop = 0.580, n = 348) and 2004 (prop = 0.392, n = 684), $p < 0.0001$). This is contrary to previous studies which recorded offensive kicks, were the technique of choice to score among winners. The observed decreased in number of warnings and utilization of defensive technique to score in 2008 winners indicates a shift form aggressive tactics to more conservative one.
Kazemi et al. (2006)	Retrospective	103 male and female TKD Olympic athletes	1	Olympic Games 2000	Ninety-eight per cent of all techniques used to score were kicks. Although not statistically significant, winners overall tended to be younger in age and taller with slightly lower BMI than their weight category average. In both male and female winners, the number of warning per match received was far higher than among non-winners.
Kwok (2012)	Observational	123 male and Female TKD athletes	1	International Asian Games	Author noted discrepancies in fighting strategies between TKD medallists and non-medallists including mode of attack, use of turning attack, and number of types of kicks employed. Round house kick was the most frequently used kick by the medalists in the competition (63.29%) while cut down kick (9.26%) and push kick

					(7.08%) were ranked second and third respectively. Aggressive mode of attack was the dominant fighting strategy used by the medalists (63.17%).
Trewin et al. (2004)	Observational	407 top-50 world-ranked swimmers.	1	Olympic Games	They concluded that a top-10 ranked swimmer who could improve performance time by 0.6%, equivalent to 0.13 s in the men's 50-m freestyle, would substantially increase chance of an Olympic medal (the difference between first and fourth place).
Zi-Hong et al. (2013)	Observational	25 elite wrestlers	-	-	They found that Olympic and World Championship medallist had the best value or was at the upper end range for the strength and power measures. They concluded that female wrestling success is not dependent on one physiological characteristic, but that a variety of physiological profiles can result in success.

Table 1.6 legend: the following abbreviations were used: BMI, body mass index; OR, Odds Ratio; TKD, taekwondo; WTF, World Taekwondo Federation.

DISCUSSION AND CRITICAL APPRAISAL

In order to critically address the myths of what constitutes a successful TKD athlete, a number of studies were conducted, which examined the characteristics of an athlete available at that time. Consistent with other literature (Cular et al. 2011; Albuquerque et al. 2012.), there was no statistical difference in average age, gender and BMI of TKD winners and non-winners (Kazemi, Perri and Casella 2009; Kazemi et al. 2006; 2010; 2014) (Table 1.1 and 1.2). We found that 2012 Olympian male winners were taller by 10cm (0.1m) compared to non-winners and to that of all male athletes during 2000-2008. This could be attributed to the 2009 rule change with regards to head shots from hard contact to head to only touching the head to score with introduction of the Electronic Protector and Scoring System (PSS). As such there has been a shift to train athletes who are taller and more flexible as they can easily touch the opponent's head. This may explain the 10cm increase in height of the male winners in Olympic 2012. Interestingly, there were no knockouts among male participants in 2012, which compared favourably with previous Olympics (see Table 1.5) and it is suggested that the 2009 change in regulations made it easier for taller participants touch the head rather than having to employ hard contact. However this does not necessarily mean less concussion. Pieter et al. (2012) is of different opinion toward awarding competitors more points (up from 1 to 4 points as of this writing) for successful spinning kicks to the head, which would appear to be counterproductive with regard to reducing the number and severity of head injuries and resulted in a reported increase in the use of kicking techniques aimed to the head as well as possible concussions. Koh and Voaklander (2016) investigated the final matches of the World TKD Championships 2011 and 2013 and found that the frequency of head kicks (HKs) seems to have increased compared with matches before 2009. A sharp increase in the numbers of HKs is evident among the elite female athletes.

To determine success in TKD, athletes are awarded points for certain manoeuvres; points can be obtained by 1) using a foot technique, 2) delivering a kick using any part of the foot below the ankle, or a fist technique, 3) delivering a punch using a tightly clenched fist to the torso. Previous studies had investigated relationships between performance and anthropometric and physical characteristics of TKD players (Gao 2001; Gao et al. 1998; Heller et al. 1998; Markovic et al. 2005; Melhim 2001; Yujin and Zeng 1999; Zhao et al. 1999). Until my work, none of these studies examined athlete profile and medalling as a measure of success (Kazemi et al. 2006). Of those techniques used by the 2000 and 2004 athletes, kicking was the predominant scoring technique for all TKD athletes (Kazemi et al. 2006; Kazemi, Perri and Casella 2009). These findings were similar to Casolino et al. (2012) in which they found younger athletes focused more on offensive techniques ($p<0.0001$) regardless of gender or match outcome. However Kwok (2012), in a comparison of different fighting strategies in TKD medallists and non-medallists at the 16th Asian Games, showed that female medallists used passive attacks more than aggressive attacks. This may have allowed them to anticipate the situation and execute their attacks earlier. In my observation, there appears to be a shift with regards to the front leg utilization to score

since the introduction of PSS and soft touch to head to score, which needs to be verified. This change opens a further avenue for future study, namely leg length and flexibility, and ability to score.

Another way we determined success and techniques used was to examine the warnings and/or deductions given at each game. During the 2004 games, there was a significant increase in the number of half point deductions warnings known as Kyong-Go (KG) and full point deduction warnings known as Gam-Jeom (GJ: one point deduction warning) compared to that in 2000 Olympic Games (Kazemi, Perri and Casella 2009). We suggested that either: athletes had adopted a more aggressive fighting style, or judges were less lenient in this regard in the 2004 Olympic Games. However, there was a significant decrease in frequency of warnings between 2004 and 2008 (Kazemi et al. 2010). Cular et al. (2011) found that females had more warnings and penalty points in the 2008 games, which exemplify a more aggressive approach; taking more risks but making more errors. Male medallists, on the other hand, produced more defensive kicks to the trunk, which, in this case, indicates a more strategic game, waiting for an opponent to make a mistake and then executing their attack. In addition, we reported that when examining the variable KGs per match (Table 1.2) TKD athletes were 1.4 times more likely to win or earn a medal in the Olympic Games (2000-2012: Kazemi et al. 2015). It was suggested that athletes taking more risks or expressing more aggressive behaviours in their matches increase the probability of them earning a medal.

KG data shows a highly significant correlation to medalling ($p=0.0078$ and 0.027 for percentage offensive points or percentage of offensive kicks, respectively) (Table 1.2) (Kazemi et al. 2015). Although the odds ratio suggested that the athletes were 1.34 times more likely to obtain a medal if more KG's are utilized in conjunction with a higher percentage of offensive techniques, percentage of offensive points alone did not show a significant correlation. More specifically, athletes were 1.29 times more likely to obtain a medal with an increase in KG's in conjunction with a higher percentage of offensive kicks used. As a precursor to aggression, Lapa et al. (2013) reported that increased levels of anger (trait anger) resulted in the success of Turkish TKD athletes both nationally and internationally suggesting that athletes with a more aggressive strategy and who were not afraid of receiving KG's, were more likely to win in competition and therefore medal. Xiong (2013) reported that athletes who had the best performance perceived anger as facilitative. The athletes in this case claimed that anger was beneficial as it created energy for the combat (Xiong, 2013). Anger is normally perceived as a negative attribute and can generate detrimental effects for the athlete if not coped with properly (Lapa et al. 2013). If there is a high level of anger it could lead to excessive levels of energy and the athlete may not be able to control this appropriately and can lead to dysfunction in performance (Xiong 2013). This is consistent with the concepts from previous research concluding that negative emotional experiences can lead to debilitating effects on athletic performance (Xiong 2013). However, with the optimal amount of anger and strategies to cope with (channel) this emotion, it is reported to help increase motivation, willingness, confidence and activeness to fight and as a consequence can result in successful performance (Lapa et al. 2013; and Xiong 2013). However, we reported that when GJ was added to KG (deduction per match, Table 1.2), it

negatively affected the chance of winning a medal (Kazemi et al. 2015). Since an athlete receives a GJ for illegal moves and behaviours, this may indicate that the athlete may have not been able to control his/her aggression in a positive way and hence, receives a full point deduction. Cular et al. (2013) reported that the WTF instructors for sparring considered the psychological profile of an athlete to have significant impact on success in TKD. Alternatively, it has also been suggested that the winning athlete is trying to avoid engagement by stepping out of boundaries, grabbing and falling in an effort to avoid being scored on by the opponent.

Another reason that the profile of winners of TKD athletes differs from other studies could be the change in rules and regulations with regards to scoring over the last 4 Olympic Games. (Appendix 1) Kazemi et al. (2014) determined that the main difference between 2012 and previous years was the introduction of the PSS, video replay and awarding points for just touching the head. No statistically significant association was found between winners versus non-winners in distribution type of score (kick or punch), or warnings for either gender. A significant odds ratio of 0.62 (CI 0.39 - 1.02) found that more kicks were associated with winning in males, but less so in females. From 2008 to 2012 the frequency of warnings per match for males increased by approximately 28.3% and deductions per match decreased by 89.9% (Kazemi et al. 2014). Among women, a decrease of 20.6% in warning and 95.9% in penalties was seen from 2008 to 2012 (Kazemi et al. 2014).

LIMITATIONS AND FUTURE CONSIDERATIONS

One of the limitations of these individual studies was the small sample size possibly resulting in a Type II statistical error. As such, this thesis has given me the opportunity to consider the data longitudinally across all four games to determine whether there were any potentially significant contributors to success that could be identified, greatly aided by utilizing the much larger sample size. However, it was determined that for factors such as BMI or age, over 400 athletes per category would be required. In order to ensure a more robust sample size, all medal winners (Gold, Silver and Bronze) were collapsed into one category; however, it is possible the results might have been different if I had considered only those who won the ultimate medal, a gold. It is not uncommon for athletes to qualify for more than one set of games. In the current study, there were 75 repeated TKD athletes during the four Olympic Games. These repeats may have skewed the results. As such, the data were analysed without these repeated athletes, including only their first appearance in the data analysis. There was no difference in the outcome, suggesting little significant bias.

The lack of some anthropometric measures could also be a limitation in these studies. The apparent relationship between arm and leg length measurements and success seems interesting and worthy of future follow up prospectively, due to possibility that increased reach might relate to an increased chance of scoring without being scored on. Moreira et al. (2014) reported that young TKD athletes with longer lower limb length appeared to be more successful, however, the sample size of this

study was very small (n=6) and the subjects were restricted to males between 12-14 years old. In apparent contrast, Sadowski et al. (2012) did not find any relationship between medalling and length of lower or upper limbs during Polish Senior Championships. Gaiani et al. 2007 did not find any relationship between success and lower limb or trunk length but with lumbar flexibility, balance and anaerobic power. Although, the data presented here (Kazemi, Perri and Casella 2009; Kazemi et al. 2006; 2010; 2014; and 2015) did not consider including any of these measurements, it might be beneficial for a future study to investigate the potential relationships between the length of upper and lower limb and success in elite TKD athletes, since the rule changes might have affected this relationship.

A final limitation was the inability to control data entry and as such could result in recording errors; data was taken from public domain (Olympic website) and was input by the officials at the match. Unfortunately, there was no detail regarding how and who collected the data.

Determining the profile of a successful TKD athlete is really a new field of study. Based on my first set of studies, there are many avenues of research still to be pursued, which can be utilized to help build that profile (Table 1.7).

Table 1.7. Summary recommendations for future taekwondo athlete profile studies

- The potential relationships between the length of upper and lower limb, and success in elite TKD athletes.
- Profile of gold medal winners versus non-winners.
- Changes in kicking and punching techniques, and strategies employed to score as a result of introduction of PSS, video replay and scoring by light contact to head.
- Inter-rater reliability and intra-rater reliability in referees.
- The effect of experience/years in TKD on winning.
- The effect of upper body/torso measurement to success.

CONTRIBUTIONS AND FUTURE RECOMMENDATIONS

To the author's knowledge, these studies were the first to investigate the profile of successful Olympic TKD Athletes and the first to use podium status as a measure of overall success. Other authors (Cular et. al., 2011; Casolino et al., 2012 and Kwok 2012) adopted this methodology later. I have studied these over 4 consecutive Olympic Games and these works have been cited by several authors (See Appendix 2). In addition, I have had the opportunity to present these studies in various conferences and symposiums globally (See Appendix 3). These papers have been made available to athletes, coaches and policy makers around the world as a means to help understand the profiles of successful TKD athlete and clarify the various anecdotal and apocryphal beliefs that might otherwise have directed the training and recruitment of future athletes (Appendices 2-3).

2. INJURY RATE AND DISTRIBUTION

BACKGROUND

Until recently, there has been very little research available regarding the injuries that TKD athletes might expect to suffer. It has been suggested that numerous factors can affect injury rates including age, experience and previous injuries (Pieter 1996; Kazemi and Chudolinski et al. 2009; and Kazemi 2012). Having been involved in TKD as both an athlete and health practitioner during 1980's and 90's, I found the level of health care to be minimal and it was imperative to elevate the level of care to at both the Provincial and National level. As a first step, it was important to accurately and systematically record injuries, which led to the creation of the Injury Report Form (IRF, Appendix 4; Kazemi and Pieter 2004). This process of recording injuries began at the 1997 Canadian National TKD Championships making injury rates and incidence easily obtainable and as a result, the first paper of its kind was published on this topic (Kazemi and Pieter 2004). For the purposes of these studies, an athlete was considered injured if any of the following conditions applied (Lindenfeild et al. 1994): 1) any circumstance that forced the taekwondo athlete to leave the competition; 2) any circumstance for which the referee or athlete had to stop competition; 3) any circumstance for which the athlete requested medical attention. In other words, the definition included so-called time-loss injuries (stoppage of a bout) as used in the NCAA Injury Surveillance System.

Therefore, the purpose of this prospective study was to assess the injury rates of Canadian TKD athletes (219 males, 99 females) relative to total number of injuries, type and body part injured. Injuries and treatment were recorded on the IRF by the health care team. As there was a paucity of information with respect to injury rates in Canadian Junior TKD athletes, we furthered our study to include this population (Pieter and Kazemi 2007).

In addition, there are a number of speculations, myths and hearsays about injuries with respect to colour-belt (beginners and novice). It has been suggested that colour-belt TKD players sustained more injuries than black belts due to lack of control and experience. Previously, there existed no data in this area to prove or disprove these conjectures. Having collected IRFs for over 9 years and covering over 58 competitions, it was decided that there was sufficient data to enable a study of injury rate, incidence, type, location and the severity with potential factors such as age and experience as well as attainment in the discipline (i.e. Black belts and colour-belts: Kazemi, Chudolinski et al. 2009).

Finally, an unexplored research area of TKD competition is the effect of pre-competition and intra-competition injury and how it might influence an athlete's performance. As a personal observation, elite athletes were able to continue competing with certain types of injury and potentially medal. However, the literature in this area is scarce (Feehan and Weller1995). To meet the requirement of a Master's degree being pursued at that point, it was decided that I examined the IRF for the Canadian National TKD team at international championships over a span of ten years to determine any

relationships between medalling as a means of success and type, frequency, location and severity of injury considering age and gender of the athlete (Kazemi 2012).

METHODS AND PROCEDURES

All four studies (Kazemi and Pieter 2004; Pieter and Kazemi 2007; Kazemi, Chudolinski, et al. 2009; Kazemi 2012) in this topic were retrospective observational studies using the IRF as the source of data. In first two studies (Kazemi and Pieter 2004; Pieter and Kazemi 2007) we were able to calculate injury rate per 1000 athlete-exposures since we had the total number of participants in the competitions. An injury was defined as any circumstance that necessitated the athlete to seek treatment from the medical personnel. Injury rates were calculated as (# of injuries/# of athlete-exposures) x 1,000 = number of injuries/1,000 athlete-exposures (A-E). One athlete-exposure (A-E) refers to one athlete being exposed to the possibility of being injured. Odds ratios (OR) were computed as well as 95% confidence intervals (CI) around the injury rates. The level of significance was set to 0.05. However in the last two studies (Kazemi, Chudolinski, et al. 2009; Kazemi 2012), due to lack of total number of participants in each competition, we only calculated the percentage of injury. A logistic regression model using Generalized Estimating Equations (GEE, see glossary) model was used to compare winners versus non-winners accounting for repeated athletes (Kazemi 2012).

RESULTS

Adult Injuries

The overall injury rates for male and female TKD athletes are described in Table 2.1. This information was further differentiated into injuries by body parts and gender. The injuries most commonly experienced by male athletes include sprain (22.8/1,000 A-E) followed by joint dysfunction (13.7/1,000A-E) whereas female athletes experienced contusions (Table 2.2). Haldeman (1992) defines joint dysfunction quoting Drum (1973) as, "Joint mechanics showing area disturbances of function without structural change; subtle joint dysfunctions affecting quality and range of joint motion. They are diagnosed with the aid of motion palpation, as well as stress and motion radiography investigation" [p. 623]. Greenman (1996) states: "Joint dysfunction is characterized by findings of misalignment, relative fixation, loss of normal range-of-motion and end-play, tenderness, and tissue texture abnormality" [p. 13–14]. Although controversial, the term has been used widely in the literature, mostly by chiropractors, physical therapists and occasionally by biomechanists and medical doctors.

Table 2.1. Injury rates (95%CI) in adult male and female Canadian taekwondo athletes at 1997 National Championships.

	Men	Women	Total
Number of athletes	219	99	318
Number of reported injuries	35	5	40
Number of athlete-exposures (AE)	438	198	636
INJURY RATES			
-- Per 100 athletes	16.0 (10.7−21.3)	5.1 (0.7−9.5)	12.6 (8.7−16.5)
-- Per 1,000 A-E	79.9 (53.4−106.4)	25.3 (3.2−47.4)	62.9 (43.4−82.4)

Table 2.1 legend: total number of subjects entered: Data presented as Mean (range); the following abbreviations were used: AE, Athlete exposure, TKD, taekwondo (Kazemi and Pieter 2004).

Table 2.2. Distribution of injuries by injury type per 1,000 athlete-exposures in adult male and female Canadian taekwondo athletes at 1997 National Championships.

	Men		Women		
Injury type	**Number**	**Rate**	**Injury type**	**Number**	**Rate**
Sprain	10	22.8	**Contusion**	3	15.2
Joint dysfunction	6	13.7	**Sprain**	1	5.1
Contusion	5	11.4	**Strain**	1	5.1
Laceration	5	11.4			
Strain	4	9.1			
Concussion	3	6.9			
Abrasion	1	2.3			
Epistaxis	1	2.3			
Total	**35**	**79.9**	**Total**	**5**	**25.3**

Table 2.2 legend: Sprain in men and contusion in women were the most common injury. (Kazemi and Pieter 2004)

Compared to international counterparts, the Canadian men and women recorded lower total injury rates (mean (range): 79.9 (53.4−106.4) and 25.3 (3.2−82.4) per 1000 athlete exposure, respectively: Table 2.3).

Table 2.3: Comparative injury rates per 1,000 athlete-exposures (95%CI) in adult martial arts athletes*.

Sport/Study	Men	Women
Taekwondo (Kazemi and Pieter 2004)	79.9 (53.4−106.4)	25.3 (3.2−82.4)
Judo (James and Pieter 2003)	48.5 (18.5−78.6)	34.3 (4.2−64.3)
Judo (Dah and Djessou 1989)	115.1 (90.9−139.3)	---
Judo (Pieter and De Cree 1997)	51.3 (1.0−101.6)	125.0 (107.7−142.3)
Judo (Pieter et al 2001)	25.2 (6.5−43.8)	41.3 (14.3−68.3)
Karate (Pieter 2000)	168.9 (144.1−193.6)	158.5 (120.0−197.1)
Karate (Dah and Djessou 1989)	65.5 (43.1−87.8)	--
Karate (McLatchie 1976)	135.6 (105.9−165.3)	--
Karate (Tuominen 1995)	157.7 (123.6−191.8)	80.4 (27.9−132.9)

Table 2.3 legend: Data presented as Mean (range encompassed by 95%CI) *Except for our own studies, injury rates are estimated based on the information provided by the author (Kazemi and Pieter 2004).

Youth Injuries

In addition to adult TKD athletes, there is a paucity of information with respect to injury rates in Junior TKD athletes. As such, a review of the literature has been provided (Table 2.4). Pieter and Kazemi (2007) were the first to examine and publish data 89 girls and 170 boys aged 6-17 years participating in a Canadian Junior taekwondo Championship. In the combined youngest age group (≤ 10 and 11-13 years), the female athletes [333/1,000 A-E (95%CI: 170.00-496.66)] sustained more injuries than the male athletes [135/1,000 A-E (95%CI: 64.10-205.14)] and the females were also at a higher risk of incurring an injury (OR=3.308, 95%CI=1.363-8.031, p=0.007) (see Table 2.5). However, there was no difference in injury rate between boys [110/1,000 A-E (95%CI: 61.73-158.05)] and girls [91/1,000 A-E (95%CI: 27.91-153.91)] in the oldest age group (14-17 years) (Table 2.6). The boys were also not at a higher risk than girls (OR=1.420, 95%CI=0.579-3.479, p=0.516). Although the total injury rate for the head and neck region was lower (31/1,000 A-E, 95%CI=14.06-47.56) than that of the lower extremities (69/1,000 A-E, 95%CI=43.71-93.73) when collapsed over gender and age group, this difference was not significant. However, there was a higher risk of sustaining an injury to the lower extremities (OR=2.386. 95%CI=1.211-4.702, p=0.010). There was a higher risk of getting injured by a roundhouse kick (OR=2.294, 95%CI=1.160-4.536, p=0.015) when collapsed over gender and age group.

Table 2.4. Injury rate in young male and female martial arts athletes, as reported in the literature.

Study	Design	Duration over which the injury was recorded	Injury Sex	Detail Number	Sample Number of participants	Rate Number of injuries per 100 athletes	Rate Number of injuries per 1,000 athlete-exposure
Judo **Pieter and De Crée (1997)**	P	1 tournament	M F	25 17	111 62	22.52 24.42	77.16 104.94
James and Pieter (2003)	P	1 tournament	M F	54 45	417 270	13.0 16.7	39.8 52.1
Karate **Tuominen (1995)**	P	-	M F	33 1	- -	- -	133.07 50.00
Pieter (1997)	P	1 tournament	M F	76 32	218 84	34.86 38.10	99.74 115.11

Taekwondo Pieter et al. (1995)	P	1 tournament	M F	20 7	139 43	14.39 16.28	78.74 97.22
Pieter and Zemper (1997a)	P	3 tournament	M F	354 87	3,341 917	10.60 9.49	58.34 56.57
Beis et al. (2001)	P	1 season	M F	76 52	1,223 767	6.21 6.78	34.23 41.27
Pieter and Kazemi (2007)	P	1 tournament	M F	31 18	170 89	18.2 20.2	108.4 132.4

Table 2.4 legend: all the data in these studies were collected via questionnaire. The following abbreviations were used P, prospective; M, Male; F, Female; (Pieter and Kazemi 2007)

Table 2.5. Injury rates per 1,000 athlete-exposures (95%CI) in young male and female Canadian taekwondo athletes

	≤ 13 years		14-17 years	
	Boys	**Girls**	**Boys**	**Girls**
#Athletes	69	35	101	54
#Injuries	14	16	20	8
#Athlete-exposures (AE)	104	48	182	88
Injury rates				
--per 100 athletes	20.29	45.71	18.81	14.82
--per 1,000 AE	134.62 (64.10-205.14)	333.33 (170.00-496.66)	109.89 (61.73-158.05)	90.91 (27.91-153.91)

Table 2.5 legend: the following abbreviations were used A-E, Athlete exposure; (Pieter and Kazemi 2007)

Table 2.6. Injury rates per 1,000 athlete-exposures (95%CI) in young male and female taekwondo athletes in literature

	≤13 years		14-17 years	
Study	**Boys**	**Girls**	**Boys**	**Girls**
Pieter and Kazemi (2007)	134.62 (64.10-205.14)	333.33 (170.00-496.66)	109.89 (61.73-158.05)	90.91 (27.91-153.91)
Beis et al. (2001)	24.85 (16.37-33.33)	28.10 (16.86-39.34)	48.21 (33.80-62.62)	68.97 (43.43-94.52)
Pieter et al. (1998)*	66.67 (28.95-104.44)	78.95 (10.39-168.29)	108.11 (33.20-183.03)	117.65 (2.36-232.94)

Table 2.6 legend: (Pieter and Kazemi 2007)

Colour-Belt versus Black-Belt Injuries

The three most common locations of presenting injury were the head (19%), foot (16%), and thigh (9%) (Table 2.7, Kazemi, Chudolinski, et al. 2009). The most common mechanism of presenting injury was found to be a defensive kick (44%), followed by an offensive kick (35%) (Figure 2.1). The most commonly

diagnosed injuries were contusions (36%), sprains (19%), and strains (15%) (Table 2.8). Colour-belts had a higher incidence of contusions, while black belts sustained more joint irritation injuries. Black belts were more likely to suffer multiple injuries (Table 2.9). Colour-belts suffered more injuries while receiving a kick, while black belts had a larger influence of past history of injury. The most common locations of injury are head, foot, and thigh respectively, and are areas for concern when considering preventative measures. This is to be expected, as the head is a vulnerable location and black belt competitors seeking competition victory would choose it as a target. However, this was a surprising finding among colored belt competitors since no contact or only light contact were allowed for colored belt competition. The colored belts' lack of experience and control may have been contributing to this higher than expected rate of head injury. Colour-belt competitors are more likely to sustain contusions, which the authors believe is due to more aggressive tactics and lack of control (Table 2.10). Those more likely to be injured tend to be younger than 18 years. Recent rule changes have no significant effect on head injuries (Kazemi, Chudolinski, et al. 2009).

Table 2.7. Percentage of injury by body region among male and female colour and black belt taekwondo athletes (age 6-58 year-old; n= 664, 447 male, 186 female; 58 competitions over 9-year span)

Body Region	Frequency	Per cent
Lower Limb	487	54.7%
Head and Neck	208	23.3%
Upper Limb	109	12.2%
Torso	87	9.8%

Table 2.7 legend: lower limb had highest injury location incidence. (Kazemi, Chudolinski, et al. 2009)

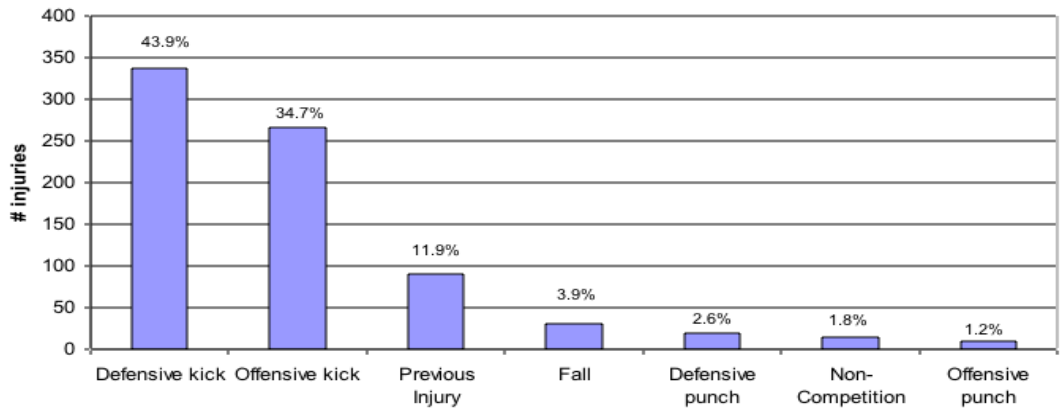

Figure 2.1. Mechanism of injury of male and female colour and black belt taekwondo athletes ((age 6-58 year-old; n= 664, 447 male, 186 female; 58 competitions over 9 year span; Kazemi, Chudolinski, et al. 2009)

Table 2.8. Percentage of injuries by diagnosis in male and female colour and black belt taekwondo athletes (age 6-58 year-old; n= 664, 447 male, 186 female; 58 competitions over 9 year span)

Diagnosis	Frequency	Per cent
Contusion	319	36.25%
Sprain	166	18.86%
Strain	129	14.66%
Fracture	69	7.84%
Joint Dysfunction	64	7.27%
Concussion	52	5.91%
Other	41	4.66%
Laceration	18	2.05%
Dislocation	11	1.25%
Epistaxis	11	1.25%

Table 2.8 legend: contusions had the highest injury type incidence. (Kazemi, Chudolinski, et al. 2009)

Table 2.9. Number of injuries versus Level of Experience in male and female colour and black belt taekwondo athletes (age 6-58 year-old; n= 664, 447 male, 186 female; 58 competitions over 9 year span)

Number of injuries	Colour belt	Per cent (%)	Black belt	Per cent (%)
Single	140	90.91	245	71.01
Multiple	14	9.09	100	28.99
Total	154	100.00	345	100.00

Table 2.9 legend: colour belts suffered more from single injuries compared to black belts. (Kazemi, Chudolinski, et al. 2009)

Table 2.10. Diagnosed injuries versus Level of Experience in male and female colour and black belt taekwondo athletes (age 6-58 year-old; n= 664, 447 male, 186 female; 58 competitions over 9 year span)

Diagnosis of injury	Colour belt	Per cent (%)	Black belt	Per cent (%)
Concussion* (statistically significant, $X_2 = 16.2138$, df = 1, $p < 0.001$)	7	4.55	31	8.99
Laceration	5	3.25	3	0.87
Contusion	74	48.05	100	28.99
Sprain	27	17.53	71	20.58
Strain	20	12.99	55	15.94
Fracture	9	5.84	26	7.54
Dislocation*	0	0.00	4	1.16
Joint irritation /dysfunction* (statistically significant, $X_2 = 12.3451$, df = 1 $p < 0.001$)	2	1.30	38	11.01
Nose bleed	2	1.30	6	1.74
Other	8	5.19	11	3.19
Total	154	100.00	345	100.00

Table 2.10 legend: * statistically significant; contusion was the most common type of injury in both groups. (Kazemi, Chudolinski, et al. 2009)

Effect of Pre-competition and Intra-Competition Injuries on Success

To the author's knowledge Kazemi (2012) is the first study to investigate the relationship between medalling and injury in taekwondo athletes. This retrospective case-series study incorporated taekwondo injuries sustained by 75 male and female elite Canadian TKD athletes over 10 years and its relationship to athletes' success by means of gaining medals during competition. A logistic regression model (GEE) was used to investigate the relationship between injuries and success.

Injury rate was associated with performance after holding variables constant (Odds Ratio (OR) 0.124, P.0.039). Moreover, with each additional injury per match, competitors were 88% (1–0.124) less likely to win a medal. Although not statistically significant, additional injuries prior to competition were associated with a 30% increase in medal prevalence (OR.1.299, P.0.203). Kazemi (2012) found when comparing athletes (gender, tournament difficulty, injury variables), a competitor who is one year older is 10% less likely to medal (OR.0.897, P.0.068) (Table 2.11). When an additional injury occurred during

competition, the athlete was 88% less likely to win a medal. As such prevention, correct diagnosis, and immediate therapeutic intervention by qualified health care providers are important (Table 2.11).

Table 2.11. Logistic regression model using GEE method Logistic regression analysis of a combination of variables for Canadian male and female medalist versus non-medalist taekwondo competitors (n=75 during 6 international championships over 10 year period).

Variables	Odds	Ratio	Std. Err.	*P* Value	95% Conf. Interval
Gender	2.266	1.291	0.151	0.742	6.923
Age	0.897	0.054	0.068	0.797	1.008
Tournament Difficulty	1.136	0.156	0.352	0.868	1.488
Pre-Competition Injuries	1.299	0.267	0.203	0.868	1.945
Competition Injury Rate	0.124	0.125	0.039	0.017	0.898

Table 2.11 legend: the following abbreviations were used Std. Err., Standard Error; (Kazemi 2012)

Lystad et al. (2009) reported the majority of the injuries to be of slight to minimal severity, which is similar to the current study. Male and female winners and non-winners had a similar rate of severe injuries during competition (Kazemi 2012) (Table 2.12). The injuries were also categorized by severity i.e. severe and non-severe. Severe injuries were defined as causing the athlete to discontinue in the competition or participating in practice as well as any fracture or dislocation. All other injuries were defined as non-severe.

It is important to examine if previous injury hinders an athlete's future ability to produce and absorb the necessary forces involved in competition. Kazemi, Chudolinski, et al. (2009) found that black belt competitors had higher rates of injury to a region if they had suffered past injury to that area.

Table 2.12. Number of injuries in Canadian male and female winners (medallist) versus non-winners (non-medallist) taekwondo competitors (n=75 during 6 international championships over 10 year period).

	All Athletes		Male		Female	
	W	**NW**	**W**	**NW**	**W**	**NW**
Pre-competition						
Total	45	60	16	29	29	31
Lower limb Non-Severe	26	35	10	16	16	19
Lower limb Severe	0	1	0	0	0	1
Head Non-severe	1	2	1	0	0	2
Head severe	0	0	0	0	0	0
Other Non-severe	18	22	5	13	13	9
Other severe	0	0	0	0	0	0
During competition						
Total	13	39	2	26	11	13
Lower limb Non-Severe	4	25	0	18	4	7
Lower limb Severe	3	2	1	1	2	1
Head Non-severe	0	1	0	1	0	0
Head severe	0	0	0	0	0	0
Other Non-severe	5	10	0	6	5	4
Other severe	1	1	1	1	0	1

Table 2.12 legend: the following abbreviations were used W, Winners; NW, Non-winners (Kazemi 2012)

Updated Literature review

An updated review of the literature for Kazemi (2012) was conducted using STARLITE mnemonic (sampling strategy, type of study, approaches, range of years, limits, inclusion and exclusions, terms used, electronic sources) (Booth 2006). PubMed/MEDLINE, CINAHL, SPORTDiscus and Rehabilitation & Sports Medicine Source databases were searched using a combination terms, "Tae Kwon Do" or taekwondo AND performance or winning AND injur* ". The search was limited to human subjects and English language, peer reviewed articles (RCTs, review of literature and cohort studies) and journals. There was no limitation with respect to the date of published papers included. Case studies and papers including mixed martial arts were excluded from this review.

This search yielded 14 citations, 5 of which were included. A second search was undertaken using the terms "Tae Kwon Do" or taekwondo AND injur*", which yielded and additional 110 citations. Five of which were included (Feehan and Waller 1995; Schlüter-Brust et al. 2011; Pieter, Fife, and O'Sullivan 2012; Lystad, Swain and Graham 2013; Engebretsen et al. 2013) (Table 2.13).

Table 2.13. Injury reports in the literature for taekwondo athletes

Study	Design	Sample size	Number of competition	Level of competition	Findings
Feehan and Waller (1995)	Q	48	1	National	No significant sex differences were found. The injury prevalence was high, but comparatively less than reported for other contact sports such as rugby football. However, one in 20 injuries was a closed head injury. No significant associations between prior injury and tournament outcome were found.
Kazemi and Pieter (2004)	R	318 athletes 40 injuries	1	National	The males (79.9/1,000 A-E) sustained significantly more injuries than the females (25.3/1,000 A-E). The lower extremities were the most commonly injured body region in the men (32.0 /1,000 A-E), followed by the head and neck (18.3/1,000 A-E). Injuries to the spine (neck, upper back, low back and coccyx) were the third most often injured body region in males (13.8/1,000 A-E). All injuries to the women were sustained to the lower extremities.
Pieter and Kazemi (2007)	R	259 athletes 58 injuries	1	National	The injury rates reported for the young Canadian TKD athletes are comparable to those of other young martial arts athletes. In the boys, there was no effect of age on injury rate. In this study, the youngest girls sustained more injuries than their older colleagues.

Kazemi, Chudolinski, et al. (2009)	R	905 injuries	58 competition-s over 9 years	Provincial	The most common mechanism of presenting injury was found to be a defensive kick (44%), followed by an offensive kick (35%). The most commonly diagnosed injuries were contusions (36%), sprains (19%), and strains (15%). Coloured belts had a higher incidence of contusions, while black belts sustained more joint irritation injuries. Black belts were more likely to suffer multiple injuries. Coloured belts suffered more injuries while receiving a kick, while black belts had a larger influence of past history of injury. The average number of injuries for athletes with repeat injuries was 2.78.
Lystad et al. (2009)	MA	8 studies, 1405 injuries in 10,947 athletes	-	National and International	Lower limb injuries occurred significantly more often than injuries to other body regions. Head and neck injuries were the second most commonly injured region. Upper limb injuries were the third most commonly injured region followed by trunk injuries. The most common type of injury was contusion and the least common was dislocation. Receiving a blow resulted in significantly more injuries than any of the other mechanisms of injury
Schlüter-Brust et al. (2011)	R Q	356 athletes 2164 injuries	-	-	Most traumas were contusions and sprains in the lower extremities. Professional TKD athletes have an increased risk of injury in comparison to recreational athletes.

Kazemi (2012)	R	75 athletes	6 over 10 years	International	For each additional injury per match (including the initial injury during the competition), competitors were 88% (1–0.124) less likely to win a medal.
Pieter et al. (2012)	SR	11 papers	-	National /International	Total injury rates for elite men varied from 20.6/1000 A–E (95% CI 11.8 to 29.3) to 139.5/1000 A–E (95% CI 94.0 to 185.1). For elite women, the rates varied from 25.3/1000 A–E (95% CI 3.1 to 47.4) to 105.5/1000 A–E (95% CI 89.8 to 121.1). About one-third of all injuries (29.6%) in the men were to the head and neck region, while almost half of the injuries (44.5%) were to the lower extremities. In women, 15.2% of injuries were to the head and neck and 53.1% to the lower extremities. The vast majority of all injuries were contusions (42.7% in the men and 62.7% in the women). Point estimates of rates of head injuries and concussions were found to be higher in TKD than in other contact sports such as football (soccer) and American gridiron football. Time-loss injury rates in the men varied from 6.9/1000 A–E (95% CI 1.8 to 11.9) to 33.6/1000 A–E (95% CI 18.9 to 8.3). In the women, they varied from 2.4/1000 A–E (95% CI 2.3 to 7.2) to 23.0/1000 A–E (95% CI 15.7 to 30.4). The turning kick was most often involved in causing injury: 56.9% of all injuries in the men and 49.8% in the women. Lack of blocking skills was identified as one of the main injury mechanisms.
Lystad et al. (2013)	MA	9 papers	-	National / International	Competing in heavier weight divisions was associated with increased overall injury incidence rates, and adolescent athletes and athletes lacking blocking skills were both found to be associated with increased occurrence of

					concussion injuries.
Engebretsen et al. (2013)	R	10 568 athletes (4676 women and 5892 men) reported 1361 injuries and 758 illnesses, equaling incidences of 128.8 injuries and 71.7 illnesses per 1000 athletes.	1	Olympic Games 2012	The risk of an athlete to be injured was the highest in taekwondo, football, BMX, handball, mountain bike, hockey, weightlifting, athletics and badminton (15–39% of registered athletes were affected in each sport). The relative injury risk was the lowest for archery, canoe slalom and sprint, track cycling, rowing, shooting and equestrian (less than 5% of the athletes were injured). The injury rates in women (132.8 injuries per 1000 athletes (95% CI 122.4 to 143.3)) and men (121.0 (112.1 to 129.9) was similar (RR=1.10 (0.97 to 1.22), p=0.11). However, male athletes were at significantly higher risk of injury in taekwondo (RR=1.9 (1.1 to 3.5), p=0.03), whereas women were at higher risk of injury in football (RR=1.7 (1.2 to 2.2), p<0.001). 0.001). Illnesses were reported from a variety of sports. In athletics, beach volleyball, football, sailing, synchronized swimming and taekwondo, just over 10% of the athletes suffered from at least one illness. The sports with the highest rate of injuries entailing a prolonged absence from training or competition (>7 days) were taekwondo (6% of the athletes), handball (5%), BMX cycling (4%) and weightlifting (4%).

Table 2.13 legend: the following abbreviations were used A-E, Athlete Exposure; MA, Meta analysis; Q, Questionnaire; R, Retrospective; SR, Systematic review; TKD, taekwondo;

DISCUSSION AND CRITICAL APPRAISAL

Severity

Severity of injury may affect an athlete's participation and performance in their sport and yet, very few authors have reported on this in TKD (Koh and De Freitas 2001; Lystad et al. 2009; Sherrill 1989). Sherrill (1989) graded injury severity on a scale of 0–10 based on time lost from full participation whereas Koh and De Freitas (2001) classified injury severity as Mild (no time lost or restriction to participation), Moderate (some disruption, less than full participation) or Severe (discontinued participation and/or referral to a hospital) and Lystad et al. (2009) recommended categorizing severity of injury as the number of days that have elapsed from the date of injury to the date of the player's return to full participation in training and match play; Slight (0–1 days), Minimal (2–3 days), Mild (4–7 days), Moderate (8–28 days), Severe (> 28 days), ''Career-Ending'' and ''Non-Fatal Catastrophic Injuries'.' However, these classifications would not be appropriate when an athlete has been provided care as a one-time situation or only during an event and as such the Abbreviated Injury Scale (AIS) (AIS, 2011) may be more applicable for rating severity during these times. This classification system was included in my revised Injury Report Form (rIRF, Appendix 5) (Table 2.14) to account for acute and on-field injuries (Kazemi 2012). Kazemi (2012) categorized injuries to severe and non-severe. Severe injuries were defined as causing the athlete to discontinue in the competition or participating in practice as well as any fracture or dislocation. All other injuries were defined as non-severe.

Table 2.14. Severity score used for Injury Report Form for Kazemi (2012)

Grade	Explanation
5	Critical
4	Requires immediate transfer
3	Requires assessment in 24hrs
2	Requires non-urgent follow up
1	Minor treatment completed at scene

Table 2.14 legend: injury severity score used in revised Injury Report Form (rIRF) in Kazemi (2012).

At the time I revised the Injury Report Form, I did not include Grade 6 injury (Unsurvivable) (Table 2.15.), having not faced this category in my 20 years experience. However, Oler et al. (1991) reported one case of a fatal kick to the head that resulted in an occipital skull fracture, bilateral subdural haematomas, contusion of the frontal and temporal lobes, and haemorrhage and herniation of the brainstem. I included an extra category to include such events on the Injury in Sparring Injury Report Form (SIRF) (Appendix 6).

Table 2.15. Severity Score used in Sparing Injury Report Form

Grade	Explanation
6	Unsurvivable
5	Critical
4	Requires immediate transfer
3	Requires assessment in 24hrs
2	Requires non-urgent follow up
1	Minor treatment completed at scene

Table 2.15 legend: injury severity score according to AIS (2011).

With each study, the Injury Report Forms have evolved. In doing so, additional information has been added to enhance the SIRF:

- Email address for the Athlete and the treating practitioner as most communications are through email
- Signature for the health practitioner under their personal info section
- Aggravating and relieving factors to the history section
- Weight category and removing the term RANK and redefining it as BELT RANK/COLOUR/DAN
- A simple consent statement on the bottom of the page with athlete and/or parent/guardian signature.

This form was renamed the Sparring Injury Report Form (SIRF) as another Injury Report Form for Poomsae exists and the required information is different (Kazemi et al. 2016).

Age

Age appears to influence injury, as younger competitors are more likely to sustain an injury than older competitors. It is unclear, however, whether this is a result of being young or lacking experience; Pieter and Zemper (1997) reported that children competing in TKD were most likely to sustain injury as a result of unblocked attacks. Koh and Cassidy (2004) reported that of 2328 competitors surveyed, 17% reported a concussion in the last 12 months prior to completing the survey and that most were associated with young age and a lack of blocking skills. Kazemi, Chudolinski, et al. (2009) also reported that those more likely to be injured tend to be younger than 18 years. While younger competitors suffered an injury as a result of receiving kicks, Kazemi, Chudolinski, et al. (2009) reported that older competitors were more likely to sustain injury while receiving a punch, and this could be a result of an older individual trying to close the distance between his or her opponent as they may lack the confidence in kicking ability with increased age.

In terms of medalling, Kazemi (2012) reported the average age of the winners was three years less than that of non-winners (22.3 vs. 25.8 years respectively). In addition, Kazemi and colleagues (Kazemi et al. 2012; 2010; 2006 and 2004) found that the average age of the female winners was less than that of male winners. It was suggested that females reach puberty earlier than males and develop skills and peak

performance earlier than their male counterparts. Using the regression model, for every year over the age of 15, an injured competitor is 10% less likely to medal (OR. 0.897, P. 0.068) (Kazemi 2012). Gaeini et al. (2009) used medal gain as a measure of success in male Iranian TKD athletes and did not find statistical significance between success and age, however this may be attributed to their small sample of male only athletes. However, They suggested that success (in means of gaining medals) in taekwondo was related to excellent waist flexibility to gain wide range of motion at waist, ability to balance to create concessive kicks in various situations and finally a high level of anaerobic power to perform fast and jerky kicks.

Pre- and Intra- Competition Injuries

Kazemi (2012) was the first to investigate the relationship between injuries that occurred before and during competition and the chance of medalling in TKD. According to Kazemi (2012), the winners tended to be more likely to enter competition with more pre-competition injuries than their non-winner counterpart and it was suggested that the majority of the pre-competition injuries were likely non-severe. In addition, the winners could have been involved in more vigilant training and a greater number of competitions previously, which resulted in more pre-competition injuries. Previous injury, assuming it is not debilitating, could serve as a ‘‘hardening effect’’ of the athlete. Dirkwinkel et al. (2008) suggested that inurement exercises (repetitive painful stimulation) performed in martial arts serves to produce trigeminal pain habituation and higher pain thresholds. Finally, one cannot discount the ‘‘winners’ mindset’’ which is to win in any circumstances. Feehan and Waller (1995) had examined the relationship between past injury and competition performance; reporting no association between past injury and competition as well as black belt and other coloured belts. When they examined the effects of these factors on competition performance, the authors’ performance score was based on the individual’s first round win or loss record as they believe the majority of matches end in the first round (Feehan and Waller 1995). First-round loss was not associated with TKD- related injury prior to competition, non-TKD injuries prior to competition, current injury at time of competition, and medication use. Conversely Kazemi (2012), who over a 10-year span, evaluated athletes in 6 international competitions, who had to win at least 4 matches to gain a medal found that for each additional injury per match (including the initial injury during the competition), competitors were 88% (1–0.124) less likely to win a medal. During competition, there is less time to recover, even from minor injuries, as an athlete has to fight an average of 4 matches on the same day to medal. Preventive strategies such as proper use of protective devices, taping, and strapping in the rules and regulation of the sport could decrease injuries in TKD, and warrant further investigation. In addition, proper and immediate care by qualified health practitioners might also be important in order to arrive at a correct diagnosis and management to return the athlete to competition as soon as possible.

Finally, Kazemi (2012) data was based on a completion of injury reports over ten years during which there were several changes in rules and regulations (Appendix 1), and may have affected the injury profile. For example, there was no TKD knockouts in 2012 Olympics which maybe attributed to the change of rules in scoring head shuts from hard contact to only touching the head which decreased the force of the kicks to

the head and hence resulted in no knockouts (Kazemi et al. 2015). This may have decreased the rate of concussion as a result of rule changes and also decreased the fear of getting knocked out, hence changing the profile of athlete and injury. However Pieter et al. (2012) is of different opinion stating that awarding competitors more points (up from 1 to 4 points as of this writing) for successful spinning kicks to the head would appear to be counter-productive with regard to reducing the number and severity of head injuries. This has resulted in a reported increase in the use of kicking techniques aimed to the head (Hanson and O'Sullivan, 2011) as well as possible concussions (Koh and Yang, 2011).

In 2013 WTF introduced another change in the rules mostly known as, "Pain is not injury", meaning that if a player falls down due to pain, they will be asked firmly and hand signalled to "Stand up" to continue the match. No more injury time will be given by centre referee unless a bloody nose, cuts, dislocation of bones, sprained ankles or broken bones are observed. However, pain is a sign of injury and failure to recognize the injury may put the athlete at greater risk of more severe injury as the author has witnessed several times.

LIMITATIONS AND FUTURE CONSIDERATIONS

There were limitations associated with Kazemi (2012). First, only injuries that had been reported to the health care provider were included in this study thereby underestimating the actual injury rate, including both during and pre-competition injuries. The current study did not ascertain if the athletes had been reporting their injuries on regular basis and what kind of injuries tend not to be reported. Since the total number of participants (other than Canadian athletes) in each competition and their injury rates and success were not recorded and hence could not be measured, perhaps AE /1000 injury rate would be a better measure of true injury rate.

In addition, no long-term follow up of the athletes was available to calculate injury time loss. Future studies should include a longitudinal data set to enable the authors to calculate the AE rate of injury and time loss. It was not possible to investigate the potential relationship between weight and height of each athlete to injury and success since the weight and height were not recorded. This will be included in future studies as these components to the rIRF (Kazemi 2012) (Appendix 5). Table 2.15 summarizes recommendations for future TKD studies.

Table 2.15. Summary recommendations for future taekwondo injury studies

- Effect of preventive strategies such as proper use of protective devices, taping, and strapping on success
- Survey of the athletes asking if they had been reporting their injuries on regular bases and what kind of injuries tend not to be reported
- The potential relationship between weight and height of each athlete to injury and success.
- The relationship between "Pain is not injury" rule and success.

- The relationship between “Pain is not injury” rule and more severe injury later on during the match
- Future studies should collect the relevant data to enable the authors to calculate the Athlete exposure rate of injury and time loss.

CONTRIBUTIONS AND RECOMMENDATIONS

To the author’s knowledge Kazemi and Pieter (2004), and Pieter and Kazemi (2007) were the first papers to investigate both adult and youth Canadian TKD injury rates and patterns, level of experience (Kazemi, Chudolinski, et al. 2009) and relationship to success (Kazemi 2012). In addition, I was the first to employ gaining medal as a measure of success and look at the relationship between injuries pre-competition and during competition and success (Kazemi 2012). This work has been well received by the industry and has been cited by several authors (Appendix 2). The creation of an IRF (Appendix 4), and a modified version (rIRF) (Appendix 5) has improved injury documentation in Canada and other countries and has allowed for a systematic way to categorize and follow an athlete’s injuries (Kazemi 2012). As result of this critical analysis SIRF (Appendix 6) was developed, which can be easily adapted for use by martial arts disciplines. This data has been presented at various conferences and symposiums around the world (See Appendix 3).

The first step to decrease injury is prevention. Multi-national and world-wide studies of the injury rate and relationship with success will bring further clarification on this relationship and can dictate the proper steps for prevention and hence improve performance and success. It is further recommended by this author that the AIS injury severity scale (AIS, 2011) be used for acute and immediate injury and the scale recommended by Lystad et al. (2009) to be used for long-term studies which will enable the investigators to calculate time loss and athlete exposure time. This will provide uniformity of injury rate assessment across studies. In order to systematically evaluate the injuries in taekwondo and provide preventative measures I concur with Pieter et al. (2012) to recommend the followings:

1. Determine the extent of the injury problem through the use of a well-designed injury surveillance system;
2. Determine the aetiology and mechanism of injuries using data from the injury surveillance system;
3. Introduce preventive measures based on information from the previous steps; and
4. Assess their effectiveness by repeating step one.

Furthermore, there are some suggestions that changing the rules may also change the severity of the injuries and hence affect the rate of success, which requires further investigation.

3. WEIGHT CYCLING/CUTTING

BACKGROUND

TKD is a weight category sport and as such, various weight loss methods have been used by athletes to ensure they make their weight class (Alderman et al. 2004; Hall and Lane 2001). Athletes practice rapid weight loss (RWL) believing that they can obtain a competitive advantage against smaller and theoretically weaker opponents. RWL has been regarded as a dangerous practice in other weight category sports (Alderman et al. 2004; Filare et al. 2001; Wenos and Amato 1998); however, the literature with respect to RWL and TKD is scarce. As a former TKD athlete myself I have witnessed the widespread practice of rapid weight loss methods and there is a true concern for the safety of TKD athletes. A search of the literature did not result in any information on the pre-competition habits of the TKD athletes with regards to weight cycling, number of injuries and treatment approaches by health care provider. As a result, I decided to investigate weight loss methods and frequency of this practice at the 1998 TKD Carding Games to determine pre-competition habits of TKD athletes' weight cycling habits (Kazemi et al. 2005; Kazemi and Shearer 2007). A survey was developed and distributed at the championship and the result from that study are the first published data on pre-competition habits of TKD athletes (Kazemi et al. 2005). Subsequently, Kazemi et al. (2005) was presented at the Sixth IOC world Congress on Sport Sciences and the American College of Sports Medicine 49th Annual Meeting, St. Louis, Missouri, 2002.

These two studies (Kazemi et al. 2005 and Kazemi and Shearer 2007) demonstrated the epidemic of weight cycling among TKD athletes. I have observed this practice as an athlete and as a medical adviser for several years but was surprised that there was only one paper (van Dijik et al. 2007) apart from my own on this very important topic in TKD. With reports of deaths of wrestling athletes trying to lose weight through dangerous practices, such as wearing garbage bags in sauna and doing aerobic exercises without drinking (Artioli et al. 2010b), the Wrestling Organization passed strict rules on weight cycling among their athletes but there was no overt concern among the TKD community or governing organizations. This concern fostered an investigation into the practice of the weight cycling among youth and its relationships to success. Using the innovative method of measuring rapid weight gain (RWG) as a measure of rapid weight loss (RWL) demonstrated by van Dijik et al. (2007) I devised and conducted a similar study at the Canadian Junior National Championships (Kazemi et al. 2011). Athletes were weighed prior to competition, then again before their first match. Body mass difference in relation to winning was compared.

METHODS AND PROCEDURES

There were 2 survey studies (Kazemi et al. 2005; and Kazemi and Shearer 2007) and 1 observational study (Kazemi et al. 2011) that comprised this section. The first survey was developed and distributed among TKD athletes competing at a National Championships with a response rate of 46.7% (Kazemi et al. 2005). The Statistica Release 6 statistical package was used for all analysis. Descriptive statistics and Pearson's chi-

square test were used. When inputting data, the original questionnaire was modified to represent the population being surveyed and was then distributed among the National Team members during National Camp Training (Kazemi and Shearer 2007). As a follow up, a second survey had 100% response rate. The Statistica Release 6 and 7 statistical packages were used for all analysis. Descriptive statistics, Pearson's chi-square, t-tests and Mann-Whitney U tests were used.

Since there was a paucity of information in the junior athletes, an observational study was conducted with 108 athletes (72 males and 36 females ages 14-17 year-old) from the Canadian Junior National competition. Descriptive statistics (proportions, means and standard deviations) were used to summarize the sample of athletes. A two factor repeated measures analysis of variance with time (weigh in versus pre fight weight) and gender was used to analyse the weight measurements. A comparison of winners (medallist) versus non-winners in terms of body mass-gain after official weigh-in was conducted using a two-sample t test. Statistical package used was "Statistica".

RESULTS

The main finding from Kazemi et al. (2005) revealed that over 53% of participants surveyed reported fasting prior to the competition. Of these individuals, 33.3% neither ate nor drank, 50% only drank, and 17% ate but did not drink, with 83% of fasting participants reported doing aerobic activity prior to competition. 54% dieted prior to competition, and 36% dieted and exercised pre-competition. A follow up study was conducted to determine if there would be any difference in these habits among the elite Canadian National team (Table 3.1).

Table 3.1. Description of weight cycling habits of taekwondo national team members and non-national team athletes who participated in the Canadian National Championships

Weight Cycling habits prior to competition	**Group A (n=28)** **2005 Study** **%**	**Group B (n=16)** **2007 Study** **%**
Fasted	53	18
No food, no fluid	33.3	6.35
Water, no food	50	12.5
Food, no fluid	17	0
Aerobic exercises in addition to no food	36	6.35

Table 3.1 legend: the following abbreviations were used: Group A, Athletes participated in National Championships; Group B, National team members; (Kazemi and Shearer 2007)

An increase from weigh-in to pre-match measurements was consistently found in both genders with no significant difference between the two groups. There was no statistical significant difference in weight gain between winners and non-winners (Table 3.2).

Table 3.2. Body mass Changes in taekwondo junior male and female athletes (14-17 year-old) Winners (medallists) vs. Non-Winners (non-medallists) in single Junior National Championships: Kg ± SD

	Weigh-in	**Pre-match**	**Difference**
Winners (Kg [SD])	60.13 (11.94)	61.23 (11.77)	1.02 (1.03)
Non-Winners (Kg [SD])	61.54 (12.21)	62.55 (11.68)	1.09 (1.11)

Table 3.2 legend: the following abbreviations were used: Kg, Kilograms; SD, Standard deviation; (Kazemi, Rahman, and De Ciantis 2011)

Updated Literature review

In addition to the literature review conducted at the time of the studies above I updated the review of the literature in Kazemi et al. (2011) using STARLITE mnemonic (sampling strategy, type of study, approaches, range of years, limits, inclusion and exclusions, terms used, electronic sources) (Booth 2006). I searched PubMed/MEDLINE, CINAHL, SPORTDiscus and Rehabilitation & Sports Medicine Source databases using a combination terms, "Tae Kwon Do" or "taekwondo AND performance or winning AND weight* ". The search was limited to human subjects and English language, peer reviewed articles (RCTs, review of literature and cohort studies) and journals. There was no limitation with respect to the date of published papers included. Case studies were excluded from this review.

This search yielded 15 papers. A second search was conducted using, "Tae Kwon Do" or "taekwondo AND weight" which yielded 48 citations of which 14 papers were deemed to be relevant (Artioli et al. 2010a,b, Koral and Dosseville 2009; Fleming and Costarelli 2009; Brito et al. 2012; Sundgot-Borgen, and Garthe 2011; Pettersson and Berg 2014a,b; Tsai et al. 2011; Pettersson, Pipping and Berg 2013; Mendes et al. 2013; Elsawy et al. 2014; İrfan 2015; Rhyu and Cho 2014; Yang et al. 2015). A subsequent hand search revealed three more papers (van Dijik, Garthe and Wisnes 2007; Khodaee et al. 2015, and Santos et al. 2016). (Table 3.3)

Table 3.3. Studies that examined effect of weight cycling on various dependent variables.

Study	Design	Sample size	Number of competition	Level of competition	Findings
Artioli et al. (2010a)	Questionnaire	822 male and female, Judo	-	-	Rapid weight loss was highly prevalent in Judo competitors. The level of aggressiveness in weight management behaviours seemed to not be influenced by the gender or by the weight class, but it seemed to be influenced by competitive level and by the age at which athletes began cutting weight.
Artioli et al. (2010b)	RCT	14 male and female, Judo	-	-	Rapid weight loss did not affect Judo-related performance in experienced weight-cyclers when the athletes had 4 h to recover.
Brito et al. (2012)	Questionnaire	580 male and female, TKD, karate and Judo	-	-	They employed an exploratory methodology through descriptive research, using a standardized questionnaire with objective questions self-administered to 580 athletes (25.0 ± 3.7 yr., 74.5 ± 9.7 kg, and 16.4% ± 5.1% body fat). A high percentage of athletes used RWL methods. On average, taekwondo athletes lose body mass within 10 days of a competition. In addition, a high percentage of athletes used unapproved or prohibited methods such as diuretics, saunas, and plastic clothing. The age at which combat sport athletes reduced body mass for the first time was also worrying, especially among strikers.

Elsawy et al. (2014)	RCT	22 female, (15 TKD and 7 Judo)	-	-	The players in the experimental group took choline tablets for one week before a competition. The results revealed significant differences between pre- and post-competition measurements of leptin, free plasma choline, urine choline and urine malondialdehyde levels; body mass was also reduced in the post-competition measurements. In conclusion, choline supplementation could rapidly reduce body mass without any side effects on biochemical levels or static strength.
Fleming and Costarelli (2009)	Questionnaire	30 male, TKD	-	National and international	A total of 87 per cent of the TKD athletes surveyed stated that they would try to reduce body weight before competition to make weight classification and 47 per cent of the athletes reported that, in their effort to reduce weight, they would use a combination of restricting energy and fluid intake and increasing energy expenditure. A total of 80 per cent of the athletes stated that they would attempt to make weight on average six to nine times a year.
İrfan Y. (2015)	Observational	56 wresters	1	-	It was discovered that elite wrestlers were subjected to quick and high level of weight losses before competitions in a very short time (1-5 days). It was seen that their hydration levels differed due to the weight loss, which was explored to be causing acute dehydration among the wrestlers.
Koral and Dosseville (2009)	RCT	20 male and female,	1	National	A combined body mass loss procedure did not have an effect on short-duration performance or visco-elastic properties of the

		Judo			muscular system. However, this procedure, in common with other methods to reduce body mass reported in the literature, did adversely affect prolonged physical performance and the psychological state of male and female elite Judo athletes.
Mendes et al. (2013)	Observational	18 male, Judo, Brazilian Jujitsu, mixed martial arts and wrestling	-	-	Weight cyclers and non-weight cyclers responded to a rapid weight loss (RWL) regimen in a very similar manner. Five per cent of body mass reduction followed by a 4 hours recovery period did not elicit measurable impairments in high-intensity upper-body intermittent performance, regardless of previous experience in rapid weight loss procedures. Chronic weight cycling did not lead athletes to become resistant to the negative effects of RWL on performance.
Pettersson and Berg (2014a)	Survey and observation	21 elite female and 47 male, combat sports	6	Elite	Given the average recovery time of 18 (wrestling, TKD) versus 8 hrs. (Judo, boxing), the former group consumed twice the amount of water, carbohydrates, protein, and fat as the latter group. In conclusion, a large proportion of the participants did not meet the recovery nutrition guidelines for carbohydrates. In addition, the discrepancy between nutrient intake and weight gain points to the physiological barriers to retaining fluids during a limited recovery time after engaging in weight making practices.

Pettersson and Berg (2014b)	Observational	61 wrestling, TKD, boxing and Judo	-	National elite	Neither weigh-in close to competition nor evening weigh-in with more time for rehydration seems to prevent hypohydration prior to competition.
Pettersson, Pipping and Berg (2013)	Qualitative study	14 TKD, Judo and Wrestling	1	National	Weight regulation has become a key component of the culture of combat sports. Athletes practice weight regulation not only to gain a physical advantage over opponents but also for purposes of identity, mental diversion, and mental advantage.
Rhyu and Cho (2014)	RCT	20 high school TKD	-	High school level	The subjects were randomly assigned to 2 groups, 10 subjects to each group: the ketogenic diet (KD) group and the non-ketogenic diet (NKD) group. Body composition, performance-related physical fitness factors (2,000 m sprint, Wingate test, grip force, back muscle strength, sit-up, 100 m sprint, standing broad jump, single leg standing) and cytokines (Iinterleukin-6, Interferon-γ, tumor necrosis factor-α) were analysed before and after 3 weeks of ketogenic diet. No difference between the KD and NKD groups in weight, %body fat, BMI and fat free mass. However, the KD group, compared to the NKD group, finished 2,000 m sprint in less time after weight loss, and also felt less fatigue as measured by the Wingate test and showed less increase in tumor necrosis factor-α. This result suggests that KD diet can be helpful for

					weight category athletes, such as TKD athletes, by improving aerobic capacity and fatigue resistance capacity, and also by exerting positive effect on inflammatory response.
Sundgot-Borgen, and Garthe (2011)	Review of literature	Olympic weight class sports	-	-	Most studies examining these issues have had weak methodology. However, results from this review indicated that a high proportion of athletes were using extreme weight-control methods and that the rules of some sports might be associated with the risk of continuous dieting, energy deficit, and/or use of extreme weight-loss methods that could be detrimental to health and performance. Thus, preventive strategies are justified for medical as well as performance reasons. The most urgent needs are: (1) to develop sport-specific educational programs for athletic trainers, coaches, and athletes; (2) modifications to regulations; and (3) research related to minimum percentage body fat and judging patterns.
Tsai et al. (2011)	Cohort	16 TKD	1	National	Mucosal immunity in elite male TKD athletes was modulated by exercise and rapid weight reduction during the training, competition and recovery period. Cumulative effects of prolonged intensive training and rapid weight reduction suppressed mucosal immunity.

van Dijik, Garthe and Wisnes (2007)	Observational and Questionnaire	342 male and female, TKD	1	International	There were no significant differences between the RWG of medal winners versus non-medal winners. The methods of weight loss most reported were food restriction, more exercise, sauna, fluid restriction and special diet. The results showed that rapid weight loss practices were used by a substantial number of elite TKD players during competition.
Yang et al. (2015)	Observational	10 male, TKD	-	Elite	Ten male TKD athletes reduced their body weight by 5% within four days (rapid weight reduction, RWR). After a recovery phase, athletes reduced body weight by 5% within four weeks (gradual weight reduction, GWR). Each intervention was preceded by two baseline measurements and followed by a simulated competition. The results point out that a rapid weight reduction negatively affected hemorheological parameters and NO signalling in RBC, which might limit performance capacity. Thus, GWR should be preferred to achieve the desired weight prior to a competition to avoid these negative effects.

Khodaee et al. (2015)	Review of literature	-	-	National and international	Weight-sensitive sports are popular among elite and non-elite athletes. Rapid weight loss (RWL) practice has been an essential part of many of these sports for many decades. Due to the limited epidemiological studies on the prevalence of RWL, its true prevalence is unknown. It is estimated that more than half of athletes in weight-class sports have practiced RWL during the competitive periods. As RWL can have significant physical, physiological, and psychological negative effects on athletes, its practice has been discouraged for many years. It seems that appropriate rule changes have had the biggest impact on the practice of RWL in sports like wrestling. An individualized and well-planned gradual and safe weight loss program under the supervision of a team of coaching staff, athletic trainers, sports nutritionists, and sports physicians is recommended.
Santos et al. (2016)	Questionnaire	TKD, 72 male and 44 female	-	National and international	Among the male athletes, 77.4% of the regional/state level and 75.6% of the national/international athletes declared to have reduced weight to compete in lighter weight categories. Among women, 88.9% of regional/state level and 88.6% of national/international level reported the use of rapid weight loss strategies. Athletes reported to usually lose ~3% of their body weight, with some athletes reaching ~7% of their body weight. The methods used to achieve weight loss are potentially dangerous to health and no difference between sexes was found.

					Four methods were more frequently used by men athletes in higher competitive levels as compared to lower levels, as follows: skipping meals (Z=2.28, *P*=0.023, η2=0.21), fasting (Z=2.337, *P*=0.019, η2=0.22), restricting fluids (Z=2.633, *P*=0.009, η2=0.24) and spitting (Z=2.363, *P*=0.018, η2=0.22). Taekwondo athletes lost ~3% of their body mass, using methods potentially dangerous for their health. Although no difference was found between sexes, lower level athletes more frequently used methods such as skipping meals, fasting, restricting fluids and spitting. Considering that these health-threating methods are more commonly used by lower level athletes, specific education programs should be directed to them.

Table 3.3 legend: the following abbreviations were used: RCT, Randomised Controlled Trials; TKD, taekwondo; hrs, hours; hr, hour

DISCUSSION AND CRITICAL APPRAISAL

Sundgot-Borgen, and Garthe (2011) reported that the use of dieting, rapid weight loss, and frequent weight fluctuation among athletes competing in weight-class and leanness sports have been considered a problem for years, but the extent of the problem and the health and performance consequences have yet to be fully examined. The results from this review indicated that a high proportion of athletes were using extreme weight-control methods and that lack of restriction in the rules of some sports might have been associated with the risk of continuous dieting, energy deficit, and/or use of extreme weight-loss methods that could be detrimental to health and performance (Sundgot-Borgen, and Garthe 2011, Frachini et al. 2012). It has been noted in various studies (Frachini et al. 2012; Koral and Dosseville 2009; and van Dijik et al. 2007) that RWL practices can affect physical and cognitive capacities including increased tension, dizziness, fatigue, increased confusion and loss of vigour. TKD is no exception. Kazemi et al. (2011) revealed that there were indeed a high percentage of young TKD athletes practicing weight cutting, which is very worrisome. The main objective of the study by Kazemi et al. (2011) was to determine if pre-competition weight cycling had an effect on overall performance (winning a medal) in Junior TKD athletes.

Current literature reveals controversy regarding weight cycling, RWL and performance, indicating a need to tease out this relationship (Artioli et al. 2010b, Koral and Dosseville 2009; Fleming and Costarelli 2009; Mendes et al. 2013). Body mass gained during the recovery period between the initial weigh-in and secondary pre-match measurements is an indirect method of measuring body mass lost during weight cycling. It is assumed that the more body mass lost during weight cycling, the more body mass will be gained during the recovery period (van Dijik et al. 2007). All athletes in our study (Kazemi et al. 2011) were allowed about 16–20 hour recovery period between the weigh-in and pre-competition measurements whereby athletes re-fed and rehydrated. Our findings and those of Mendes et al. (2013) suggest that pre-competition weight cycling has no significant effect on overall competitive performance in both male and female weight classes following a recovery period (Kazemi et al. 2011). Artioli et al. (2010b) investigated weight cycling amongst Judo athletes and found subjects who lost body mass proceeded to regain 51 ± 13% of their body mass loss during a 4-hour recovery period between weight-in and performance evaluation, similar to our study, they found it did not affect performance in experienced weight cyclers who had 4-hours of recovery. Kazemi et al. (2011) reported both males and females gained less than 0.5% of their body mass back between weight-in and pre-match which is considerably less than the body mass gain values found by Artioli et al. (2010a) and Mendes et al. (2013). Gender and age may account for these differences. Kazemi et al. (2011) looked at both male and female athletes as opposed to only male athletes (Artioli et al. 2011) and these participants were 4 years younger compared to Artioli et al. study. It was suggested that the TKD athletes had less experience at RWL and recovery than the Judo participants (Artioli et al. 2010a). We further suggested that the discrepancy between sexes maybe due to the differing weight loss methods undertaken by female and male athletes in those groups to re-hydrate and feed during the recovery period (Kazemi et al. 2011). However, it cannot be discounted that these differences may also be due to the sport specific variability between Judo and TKD. Mendes et al. (2013) concluded that chronic weight cycling did

not protect athletes from the negative impact of RWL on performance. The time to recover after weigh-in and the patterns of food and fluid ingestion during this period was likely to play the major role in restoring performance to baseline levels (Mendes et al. 2013).

Since RWL seems to have no benefits on overall performance, the incentive for TKD athletes to subject themselves to this potentially harmful practice is not justified. Monitoring dietary habits of athletes in weight classed sports is recommended since most weight class athletes compete 5–10% under their natural BM and do this up to 10 times a year. It is prudent to assume that larger BM losses and more frequent dieting could potentially result in negative physiological and performance consequences. Twenty per cent of the athletes reported that they had never received advice on healthy eating and appropriate weight loss practices (Fleming and Costarelli 2009). It is clear that athletes in weight-classed sports are not receiving adequate education regarding the potential health risks and negative performance outcomes associated with weight cycling. Sundgot-Borgen, and Garthe (2011) recommended preventive strategies for medical as well as performance reasons, which I consider very appropriate. They recommended 3 most urgent needs: (1) to develop sport-specific educational programs for athletic trainers, coaches, and athletes; (2) modifications to regulations; and (3) research related to minimum percentage body fat and judging patterns.

Considering the ill effect of RWL and the widespread practice among young and adult martial arts athletes, one solution to protecting the athletes may lie in utilization of different categorization system (Frachini et al. 2012). Dubnov-Raz et al. (2015) suggested using height as the categorization rather than weight especially in striking martial arts such as karate and TKD. They examined if height categories could be used as an alternative to weight categories for competition, in order to protect the health of athletes. Height and weight of 169 child and adolescent competitive karate athletes were measured. Participants were divided into eleven hypothetical weight categories of 5 kg increments, and eleven hypothetical height categories of 5 cm increments. They calculated the coefficient of variation of height and weight by each division method. They also calculated how many participants fit into corresponding categories of both height and weight, and how many would shift a category if divided by height. They found a high correlation between height and weight ($r = 0.91$, $p<0.001$). The mean range of heights seen within current weight categories was reduced by 83% when participants were divided by height. When allocating athletes by height categories, 74% of athletes would shift up or down one weight category at most, compared with the current categorization method (Dubnov-Raz et al. 2015). They concluded that dividing young karate athletes by height categories significantly reduced the range of heights of competitors within the category thereby athletes may not be competing against much heavier opponents (Dubnov-Raz et al. 2015). They reported two sports in which heights were used for contestant grouping and equality. In Nunchaku fights, competitors are divided by 10 cm height categories, exhibiting the importance of arm length in this striking-type martial art. In ski jumping, the maximal ski length allowed is related to the total body height and BMI of the competitor (Dubnov-Raz et al. 2015).

I agree with Dubnov-Raz et al. (2015) that utilization of height category will decrease the RWL practices, which are demonstrated to be harmful with no advantage in performance. Since the TKD rule

changes in 2009 allowing scoring the head shots with light contact, I have witnessed several shorter but very skilled elite athletes lose to their taller counterparts. As such I believe that changing the rules to utilize height category will provide shorter athletes with a fair competition and possibly revolutionize competition in striking martial arts. Another issue with weight category especially in the adolescents has been puberty; in other words, a rapid growth rate and trying to stay in the same weight category before the growth spurt, drove an increase in the RWL practices in this age group. RWL practice at the time that the body of the growing adolescent requires more nutrients is logically not healthy. Height category will stop this practice since you cannot alter your height. Incorporating height divisions in my opinion will also promote proper nutrition, strength training and muscle development and encourages the athletes to compete in their natural weight. Further investigation into these variables needs to be conducted.

In the past height categories were used for boys and girls (6-11 years old) TKD athletes (Table 3.4). However, to this author's knowledge there are no such height categories for other age groups in TKD. As such much work still needs to be done in this area to examine the effectiveness of height classification to eradicate RWL practices.

Table 3.4. Height categories for boys and girls (6-11 years old) taekwondo athletes, which were used for local tournaments previously.

Height category	Height	Boys	Girls
Group 0	Not over 120 cm.	Not over 6 years old	Not over 6 years old
Group 1	Over 120 cm. to 128 cm	Not over 8 years old	Not over 8 years old
Group 2	Over 128 cm. to 136 cm	Not over 10 years old	Not over 10 years old
Group 3	Over 136 cm. to 144 cm	Not over 10 years old	Not over 10 years old
Group 4	Over 144 cm. to 152 cm	Not over 11 years old	Not over 11 years old
Group 5	Over 152 cm. to 160 cm	Not over 11 years old	Not over 11 years old
Group 6	Over 160 cm. to 168 cm	Not over 11 years old	Not over 11 years old

Table 3.4 legend: the following abbreviations were used: cm, centimetre;

The Centres for Disease Control and prevention (CDC) values for stature-for-age and weight –for-age percentiles charts for 2-20 years boys and girls (Appendix 8) were used to formulate my proposed height categories for TKD (CDC 2015) (Tables 3.5-3.9). The current number of categories per age group was retained in order to make the transition easier. For example, there are currently 10 weight categories in Cadet age group (WTF 2015), which were matched with 10 height categories based on stature-for-age and weight –for-age percentiles charts (CDC 2015). I decided to start with the fifth percentile height and weight at the youngest age (12 years old), which was the lowest height to highest (95-percentile) height in 14 years of age with increment of 5cm according to the CDC charts (Appendix 8). This nicely matched the current WTF weight category for each height. For Olympic division (youth and senior) where there is only half the

number of world championships divisions, I used 10 cm increments. In this way no extra division needed to be added to the competitions and would be easier to convert them to height classification.

Table 3.5. Proposed competition height categories for cadet taekwondo athletes (12-14 years old).

Height category	Female height (cm)	Current Weight category (Kg)	Male height (cm)	Current Weight category (Kg)
1	<134.9	Under 29	<139.9	Under 33
2	135-139.9	29-33	140-144.9	33-37
3	140-144.9	33-37	145-149.9	37-41
4	145-149.9	37-41	150-154.9	41-45
5	150-154.9	41-44	155-159.9	45-49
6	155-159.9	44-47	160-164.9	49-53
7	160-164.9	47-51	165-169.9	53-57
8	165-169.9	51-55	170-174.9	57-61
9	170-174.9	55-59	175-179.9	61-65
10	>175	Over 59	>180	>65

Table 3.5 legend: the following abbreviations were used: cm, centimetre; Kg, Kilograms

Table 3.6. Proposed competition height categories for junior taekwondo athletes (14-17 years old).

Height category	Female height category (cm)	Current Weight category (Kg)	Male height category (cm)	Current Weight category (Kg)
1	<139.9	<42	<149.9	<45
2	140-144.9	42-44	150-154.9	45-48
3	145-149.9	44-46	155-159.9	48-51
4	150-154.9	46-49	160-164.9	51-55
5	155-159.9	49-52	165-169.9	55-59
6	160-164.9	52-55	170-174.9	59-63
7	165-169.9	55-59	175-179.9	63-68
8	170-174.9	59-63	180-184.9	68-73
9	175-179.9	63-68	185-189.9	73-78
10	>180	>68	>190	>78

Table 3.6 legend: the following abbreviations were used: cm, centimetre; Kg, Kilograms

Table 3.7. Proposed competition height categories for Youth Olympic taekwondo athletes (16-17 years old).

Height category	Female height (cm)	Current Weight category (Kg)	Male height (cm)	Current Weight category (Kg)
1	<144.9	<44	<154.9	<48
2	144.9-154.9	44-49	155-164.9	48-55
3	155-164.9	49-55	165-174.9	55-63
4	165-174.9	55-63	175-184.9	63-73
5	>175	>63	>185	>73

Table 3.7 legend: the following abbreviations were used: cm, centimetre; Kg, Kilograms

Table 3.8. Proposed competition height categories for senior taekwondo athletes (≥18 years old).

Height category	Female height (cm)	Current Weight category (Kg)	Male height (cm)	Current Weight category (Kg)
1	>149.9	<47	<159.9	<54
2	150-154.9	47-51	160-164.9	54-58
3	155-159.9	51-55	165-169.9	58-62
4	160-164.9	55-59	170-174.9	62-67
5	165-169.9	59-63	175-179.9	67-72
6	170-174.9	63-67	180-184.9	72-78
7	175-179.9	67-72	185-189.9	78-84
8	>180	>72	>190	>84

Table 3.8 legend: the following abbreviations were used: cm, centimetre; Kg, Kilograms

Table 3.9. Proposed competition height categories for senior taekwondo Olympic athletes (≥18 years old).

Height category	Female height (cm)	Current Weight category (Kg)	Male height (cm)	Current Weight category (Kg)
1	<159.9	<49	<169.9	<58
2	160-169.9	49-57	170-179.9	58-68
3	170-179.9	57-67	180-189.9	68-80
4	>180	>67	>190	>80

Table 3.9 legend: the following abbreviations were used: cm, centimetre; Kg, Kilograms

LIMITATIONS AND FUTURE CONSIDERATIONS

There were a few limitations in these studies. First and most important, was the failure to record the methods of weight cycling employed by participating athletes in Kazemi et al. (2011). In addition, the question of who provided the information to athletes regarding how to lose weight was absent in all my studies (Kazemi et al. 2005; Kazemi and Shearer 2007; Kazemi et al. 2011). The methods of RWL employed could have shed some light into the physiological and psychological states of the competitors. It may have elicited why there were differences in pre-match weight gain between different weight classes, and determined the severity of the RWL practices being conducted in TKD today. Also, different methods of RWL may have manifested in different associated symptoms, and could have affected performance in various ways. The methods of recovery employed by athletes during the 16–20 hour recovery period are unknown and act as another limitation in this study (Kazemi et al. 2011). Finally, sample size was a limitation. For each study, there were a relatively small number of respondents thus limiting the descriptive statistics. Future studies should include more robust sample sizes.

It would be interesting to study the effects of RWL on athletes that were not allowed a recovery period following weigh-in. Currently, this does not follow real world scenarios as recovery periods of various durations are allowed in TKD tournaments. However, such a study can potentially demonstrate if RWL itself results in negative effects on performance. The other area to be explored is the effect of RWL on endurance sports versus anaerobic sports. The future studies should include a survey about the methods used by athletes to achieve desired weight, duration of practice in a larger adult sample size. A longitudinal study following and recording an athlete's weights prior to the season and before the competition will also give a better picture of weight loss practices. The ideal future research would be a multi-centre global interprofessional collaborative investigation of weight loss practices among TKD athletes, the starting age, advices received and from whom, challenges faced, methods used such as fasting, exercise, plastic clothing, medication etc. via a survey. This study could be followed by investigating the athlete's weight prior to the season, mid season and prior to important competitions and correlation to success. This will hopefully lead to develop a best practice document to advise the stakeholders.

Table 3.10. Summary recommendations for future taekwondo weight cutting studies

- Effects of RWL on performance in athletes without any recovery period following weigh-in
- Effect of RWL on endurance sports versus anaerobic sports performance
- A multi-centre global interprofessional collaborative investigation of weight loss practices among TKD athletes, the starting age, advices received and from whom, challenges faced, methods used such as fasting, exercise, plastic clothing, medication etc. via a survey
- Followed by investigating the athlete's weight prior to the season, mid season and prior to important competitions and correlation to success.
- Effectiveness of height classification in reducing RWL practices
- Satisfaction rate of athletes, coaches, parents and medical staff with height classification

CONTRIBUTIONS AND RECOMMENDATIONS

I have presented these studies in various national and international conferences and symposiums (See Appendix 3). I have also provided these papers to athletes, coaches and policy makers around the world. Unfortunately, there have not been any changes in the policies, rules and regulations yet. I will continue lobbying the policy makers at WTF for regulation and monitoring weight cycling practices among TKD athletes. I agree with Franchini et al. (2012) and recommend the followings to discourage the practice of RWL and prevent its ill effect on the health of TKD and other weight sports athletes:

- Matches should begin in less than 1 hour after weight in;
- Each athlete is allowed to weigh-in only one time;
- RWL methods and artificial rehydration methods are prohibited on competition days;
- Athletes must pass the hydration test to get the weigh-in validated;
- An individual minimum competitive weight is determined at the beginning of each season;
- No athletes are allowed to compete in a weight class that would require weight loss greater than 1.5% of body mass per week.
- Regular unannounced spot weight checks of the athletes.

By employing these rules and regulation we will be able to discourage athletes from practicing RWL and protect them from the ill effect.

However, in my opinion the ultimate solution to put an end to weight cutting practices is to use Height categories instead. I have devised height categories for all age groups in TKD, which I will be lobbying to WTF. Further investigation into the effectiveness of height versus weight categories is recommended.

CONCLUSIONS

TKD, a Korean striking martial art, has been an Official Olympic Sports since 2000. As such there are great efforts on behalf of athletes, coaches, researchers and health care professionals to identify the perfect formula to get on the podium. I am the first researcher to use gaining podium status in TKD as a measure of success. I investigated the relationships between success and injury, profile and weight cycling. I found athletes with more aggressive strategy who are not afraid of receiving KGs are more likely to win in competition and receive a medal.

Severe injuries have been associated with a decreased chance of winning. To the author's knowledge Kazemi (2012) was the first to study the relationship between success and injuries during and prior to competition over 10-year period in elite TKD athletes. I found any additional injury during competition decreased the chance of medalling by 88%. Further research utilizing athletes from different countries is required to examine this finding among other nations. I have also published two Injury Report Forms expanding the second form to include the mechanism of injury and injury severity scale, as there was a lack of proper severity reporting in the literature (Kazemi 2012: Appendix 5). I have revised the rIRF as a result of this critical analysis to include full Injury severity scale along with other revisions (Appendix 6). These forms have been widely utilized nationally by Canadian TKD Association and internationally.

There is an endemic problem of weight cycling among martial artists including TKD athletes in hope of increase chance of winning. The elite TKD athletes seemed to have better strategies in weight cycling than novice athletes. There has been no correlation between amount of RWL and winning a medal or not, which may be a result of the recovery period between weigh-in and competition and the anaerobic nature of TKD. However, this does not eliminate the risks associated with RWL. To date there are no guidelines or bylaws set by WTF with regards to weight cycling and RWL. It is this author's recommendation that monitoring weight loss program, prohibiting RWL methods and artificial rehydration methods, weighing in the athletes 1 hour prior to the match and only once, disqualification in case of more that 1.5% body mass loss in a week, passing a hydration test, competitive weight determination in the beginning of the season and frequent unannounced spot weight checks be instituted by WTF for the safety of the athletes. Alternatively, I believe utilizing the height category instead of weight would significantly decrease the practice of RWL and it's ill effects on the athletes and provide a more even playing field with respect to competition in striking martial arts. Further investigation of this hypothesis is necessary.

The central theme of my 3 portfolio projects is success in means of acquiring medal. My studies (Kazemi et al. 2006; Kazemi, Perri and Casella 2009; Kazemi et al. 2010; Kazemi et al. 2013; Kazemi et al. 2014; Kazemi et al. 2015; Kazemi and Pieter 2004; Pieter and Kazemi 2007; Kazemi, Chudolinski, et al. 2009; Kazemi 2012; Kazemi et al. 2005; Kazemi and Shearer 2007; and Kazemi et al. 2011) have demonstrated that for a sparing taekwondo athlete to succeed to the podium in safest and healthiest way the athlete should:

1. Avoid injuries during the match (specially severe injuries) possibly by proper utilization of protective devices, proper defensive techniques and utilization of qualified health care practitioners to address and correct any biomechanical and or medical conditions and injuries;
2. Avoid RWL (loss of 5% of body weight per week) and hazardous related practices such as use of diuretics, laxatives, sauna and plastic clothing, vomiting and severe dehydration, but practice gradual, healthy, and medically supervised and directed weight management (loss of less then 1.5% body weight per week) with maintenance of proper hydration and nutrition; and
3. Use a more aggressive strategy with offensive kicking and punching with no fear of receiving KGs but avoid receiving GJs.

In summary, although many aspects of the work I have performed were ground breaking in this area, they are not perfect and would benefit from further investigations. Conducting this PhD thesis helped me to realize the shortcomings and plan my future studies to investigate the missing pieces. My future studies will look into the relationships between torso, upper limb and lower limb length and success, and injury; experience/years of practicing TKD and or degree of black belt and success; relationship between weight and success in each weight category; relationship between number of head kicks received and concussion and success; long term longitudinal investigation of weight cycling and success and physiological changes in long term weight cyclers. Investigation of my proposed height category to decrease RWL and its ill effects is necessary to provide evidence for this fundamental change. I am planning to expand my investigations globally and collaborate with colleagues to conduct multi-centre, multi-cultural studies during world championships to improve the picture of weight cycling, injury, profile and success.

The unique methodology, data collection and Injury Reports Forms developed are useful in other sports. Since the ultimate goal of athletes and coaches is to make it to the podium, medalling can be easily used in all sports performance research. RWG as a measure of RWL is unique and can be easily applied to weight class sports investigations. The Injury Report Forms (Appendices 4-6) can be easily used for various sports especially in martial arts to record injuries consistently and efficiently and can also be used for retrospective research (Appendix 6).

The conclusions in the previous chapters have illustrated the situation as it was at that time. There have been rule changes that may have impacted on the way the sport is played, in which case will affect who wins and the characteristics of the winner. These need to be the focus of future studies. As a result of conducting this PhD thesis I feel I am now in a better position to ask the right and most appropriate questions in order to determine “what makes the successful TKD athlete”.

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APPENDICES

Appendix 1

TKD scoring and changes

In TKD, points can be obtained by using a foot technique: delivering a kick using any part of the foot below the ankle, or a fist technique: delivering a punch using a tightly clenched fist to the torso. In 2003, rule changes introduced an increase in point value of head contacts in adult competition to 2-points, compared to a standard 1-point value for kicks to the torso as well as an additional point for an eight-count knockdown. During the 2012 Olympics, there were additions made to the scoring possibilities for kicks used in each match. Like previous years, athletes were still awarded 1 or 2 points for their offensive or defensive kicks. However, in 2012, the athletes also obtained a score of 3 or 4 for offensive or defensive kicks by landing a kick to the head or a turning kick to the head respectively, which was not seen in previous years. Furthermore, the most important change were utilization of Electronic Protector and Scoring System (PSS), video replay allowance to dispute the points awarded by coaches and decrease the force of head shuts to only touching the head to score compared to full force to move and stunt the player or knock down to score.

Penalties are considered prohibited acts in TKD. Two types of penalties exist: Kyong-Go (KG) and Gam-Jeom (GJ). A KG is a warning penalty; two KG's in a match are counted as a deduction of one point for the athlete. GJ is a deduction penalty and is counted as a deduction of one point for the participant who used illegal moves or behaviours. In our data set, deductions per match (ded. per match), is a combination of both GJ's received and a sum of every two KGs within a single match.

Appendix 2. Citations

https://scholar.google.ca/citations?hl=en&user=o2wFijkAAAAJ

ALSO SEE: https://www.researchgate.net/profile/Mohsen_Kazemi7/stats/citations

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Appendix 3. Conference Presentations

1. Kazemi M, Hua G, Ingar A, and Jaffery A. Injuries in Elite taekwondo Poomsae Athletes. World Federation of Chiropractic Symposium, Athens, Greece, May 16, 2015.

2. Kazemi M, Cardenas A, Chan A, and Cheng R. Profile of Olympic taekwondo athlete medallists in four consecutive Olympic Games. FICS Symposium Athens, Greece, May 13, 2015.

3. Kazemi M, Hua G, Ingar A, and Jaffery A. Injuries in Elite taekwondo Poomsae Athletes. The 5th International Symposium for taekwondo Studies, Chelyabinsk, Russia, May 9-10, 2015 page 28.

4. Kazemi M, Cardenas A, Chan A, and Cheng R. Profile of Olympic taekwondo athlete medallists in four consecutive Olympic Games. The 5th International Symposium for taekwondo Studies, Chelyabinsk, Russia, May 9-10, 2015 page 122.

5. Kazemi M, Ong M, Pacis A, and Tseng K. A profile of 2012 Olympic Games TKD athlete. Poster presentation, ACC-RAC, Orlando, Florida, USA, March 20-22, 2014.

6. Kazemi M, De Ciantis M, and Rahman A. A Profile of Youth Olympic Tae Kwon Do Athlete. Poster presentation at 4th International Symposium on TKD Studies, Puebla, Mexico, July 16-17, 2013.

7. Kazemi M, De Ciantis M, and Rahman A. A Profile of Youth Olympic Tae Kwon Do Athlete. Poster presentation at FICS (Federation Internationale de Chiropractique du Sport) Symposium, Durban, South Africa, April 9, 2013.

8. Kazemi M. Relationship between success and injury in elite Tae Kwon Do athlete. Poster presentation 3rd International Symposium on TKD Studies, Gyeongju, Korea April 29-30, 2011.

9. Kazemi M, De Ciantis M, and Rahman A. Weight cycling in young Tae Kwon Do Athlete. Podium presentation 3rd International Symposium on TKD Studies, Gyeongju, Korea April 29-30, 2011.

10. Kazemi M. Relationship between success and injury in elite Tae Kwon Do athlete. Poster presentation at World Federation of Chiropractic (WFC) 11th Biennial Congress, Rio de Janeiro, Brazil, April 7-9, 2011.

11. Kazemi M. Relationship between success and injury in elite Tae Kwon Do athlete. Podium presentation at FICS (Federation Internationale de Chiropractique du Sport) Symposium, Janeiro, Brazil, April 6, 2011.

12. Kazemi M, Perri G, and Soave D. 2008 Olympic Tae kwon Do Athlete Profile. Poster presentation at ACC-RAC 2010, Las Vegas, March 19-20, 2010.

13. Kazemi M, Chudolinski A, Turgeon M, Simon A, Ho E, and Coombe L. Nine year Longitudinal Retrospective Study of TKD Injuries. Podium presentation at 2nd International Symposium on TKD Studies, Copenhagen, Denmark, October 12-13, 2009.

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16. Kazemi M, Perri G, and Casella C. 2004 Olympic 2004 TKD Athlete profile. Poster presentation at WFC′s 10th Biennial Congress, Montreal, Quebec, April 30-May 2, 2009.

17. Kazemi M, and Shearer H. Differences in Pre-Competition Habits between National Team and other Competitive TKD Athletes. Proceeding of 1st International Symposium for TKD Studies, Beijing, China, May 16-17, 2007.

18. Pieter W, and Kazemi M. Competition Injuries in Young Canadian TKD Athletes. Proceeding of 1st International Symposium for TKD Studies, Beijing, China, May 16-17, 2007.

19. Kazemi M, Morgan CJ, and White AR. Sydney Olympics 2000 TKD Athlete Profile. Proceedings of the 7th IOC Olympic World Congress on Sport Sciences. Athens, Greece, October 7-11, 2003.

20. Kazemi M, Shearer H, and Choung YS. Pre-Competition Habits and Injuries in TKD Athletes. Sixth IOC world Congress on Sport Sciences and the American College of Sports Medicine 49th Annual Meeting, St. Louis, Missouri. Proceedings page 41.

21. Kazemi M, and Pieter W. Injuries in Young TKD Athletes. Sixth IOC world Congress on Sport Sciences and the American College of Sports Medicine 49th Annual Meeting, St. Louis, Missouri. Proceedings page 66.

22. Kazemi M, and Pieter W. Injuries at a 1997 national TKD championship in North America. First World Congress on Fighting Sports and martial arts, Proceedings, page 33, March 2000.

Appendix 4. Injury Report Form

Injury Report Form **Date:** **Time:**

EVENT:	PLACE:		
NAME:	BIRTHDATE:	AGE:	SEX: M F
ADDRESS:		CITY:	
PROVINCE:	POSTAL CODE:	PHONE:	
HEALTH CARD NO:			
NAME OF TKD SCHOOL:		RANK:	
TO BE COMPLETED BY MEDICAL PERSONNEL			
NAME:		TITLE:	
CLINIC LOCATION:		PHONE:	
Past History: **Location:** **Radiation:** **Character & Intensity:** **Mechanism of Injury**			
Examination Findings:			
Diagnosis:			
Recommendations:			
Treatment Rendered:			
Follow-up:			
Discharge Instructions:			

SIGNATURE:

Appendix 5. Revised Injury Report Form

Revised Injury Report Form **Date:** **Time:**

EVENT:	PLACE:		
NAME:	BIRTHDATE:	AGE:	SEX: M F
ADDRESS:		CITY:	
PROVINCE:	POSTAL CODE:	PHONE:	
HEALTH CARD NO:	BODY MASS:	HEIGHT:	
NAME OF TKD SCHOOL:	RANK:		
TO BE COMPLETED BY MEDICAL PERSONNEL			
NAME:	OCCUPATION:		
CLINIC LOCATION:		PHONE:	

Past History:
Location:
Radiation:
Character & Intensity:
Mechanism of Injury:

- **Attacking Kick**
- **Received Kick**
- **Blocked Kick**
- **Punched**
- **Pushed**
- **Tripped**
- **Collision**
- **Other**

ABILITY TO COMPLETE MATCH

Unable to Continue
(Round) 1 2 3 SD*
Completed Match

*** Sudden Death**

Examination Findings:

SEVERITY SCORE:

5 Critical
4 Requires immediate transfer
3 Requires assessment in 24hrs
2 Requires non-urgent follow up
1 Minor treatment completed at scene

Diagnosis:

Recommendations:

Treatment Rendered:

Follow-up:

Discharge Instructions:

SIGNATURE:

Appendix 6. Revised Injury Report Form 2

Sparring Injury Report Form **Date:** **Time:**

EVENT:	PLACE:		
NAME:	BIRTHDATE:	AGE:	SEX: M F
ADDRESS:		CITY:	
PROVINCE:	POSTAL CODE:	COUNTRY:	
PHONE:	EMAIL:	WEIGHT CATEGORY:	
HEALTH CARD NO:	BODY MASS:	HEIGHT:	
NAME OF TKD SCHOOL:	BELT RANK/Colour/Dan:		
TO BE COMPLETED BY MEDICAL PERSONNEL			
NAME:	OCCUPATION:		
CLINIC LOCATION:	PHONE:		
EMAIL:	SIGNATURE:		

Past History:
Location:
Radiation:
Character & Intensity:
Aggravating factors:
Relieving factors:
Mechanism of Injury:

- **Attacking Kick**
- **Received Kick**
- **Blocked Kick**
- **Punched**
- **Pushed**
- **Tripped**
- **Collision**
- **Other**

ABILITY TO COMPLETE MATCH

Unable to Continue (Round) 1 2 3 SD*

Completed Match

ALLERGIES:

*** Sudden Death**

Examination Findings:

SEVERITY SCORE:

6 Unsurvivable
5 Critical
4 Requires immediate transfer
3 Requires assessment in 24hrs
2 Requires non-urgent follow up
1 Minor treatment completed at scene

Diagnosis:

Recommendations:

FIT TO CAMPETE NOT FIT TO COMPETE

Treatment Rendered:

Follow-up:

Discharge Instructions:

I have been informed of the risks involved and consent to the treatment and recommendations stated above.

Athlete Signature: **Date:**

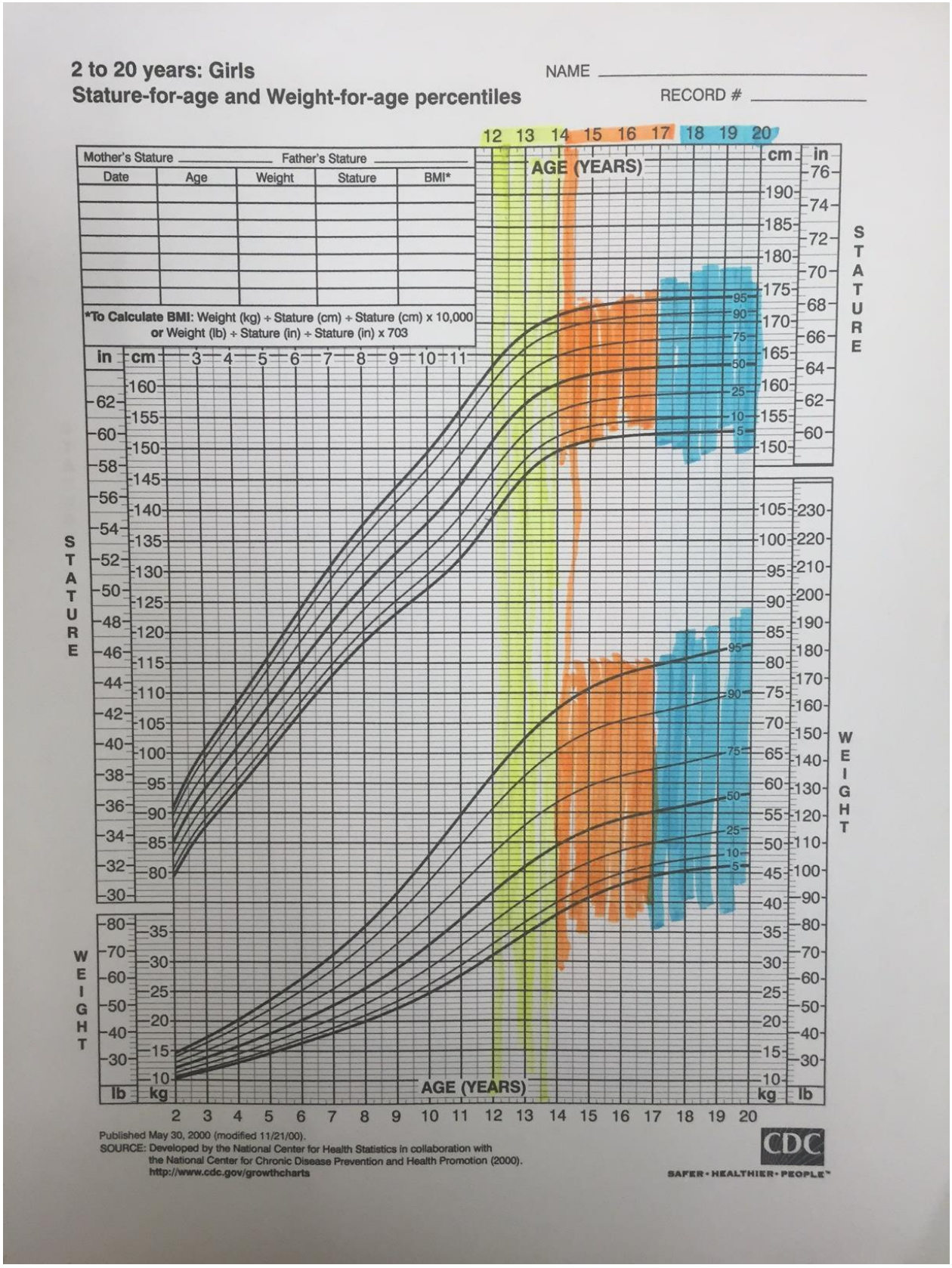
Parent/guardian name: **Signature:** **Date:**

Appendix 7. Published articles

Please see attached PDF files

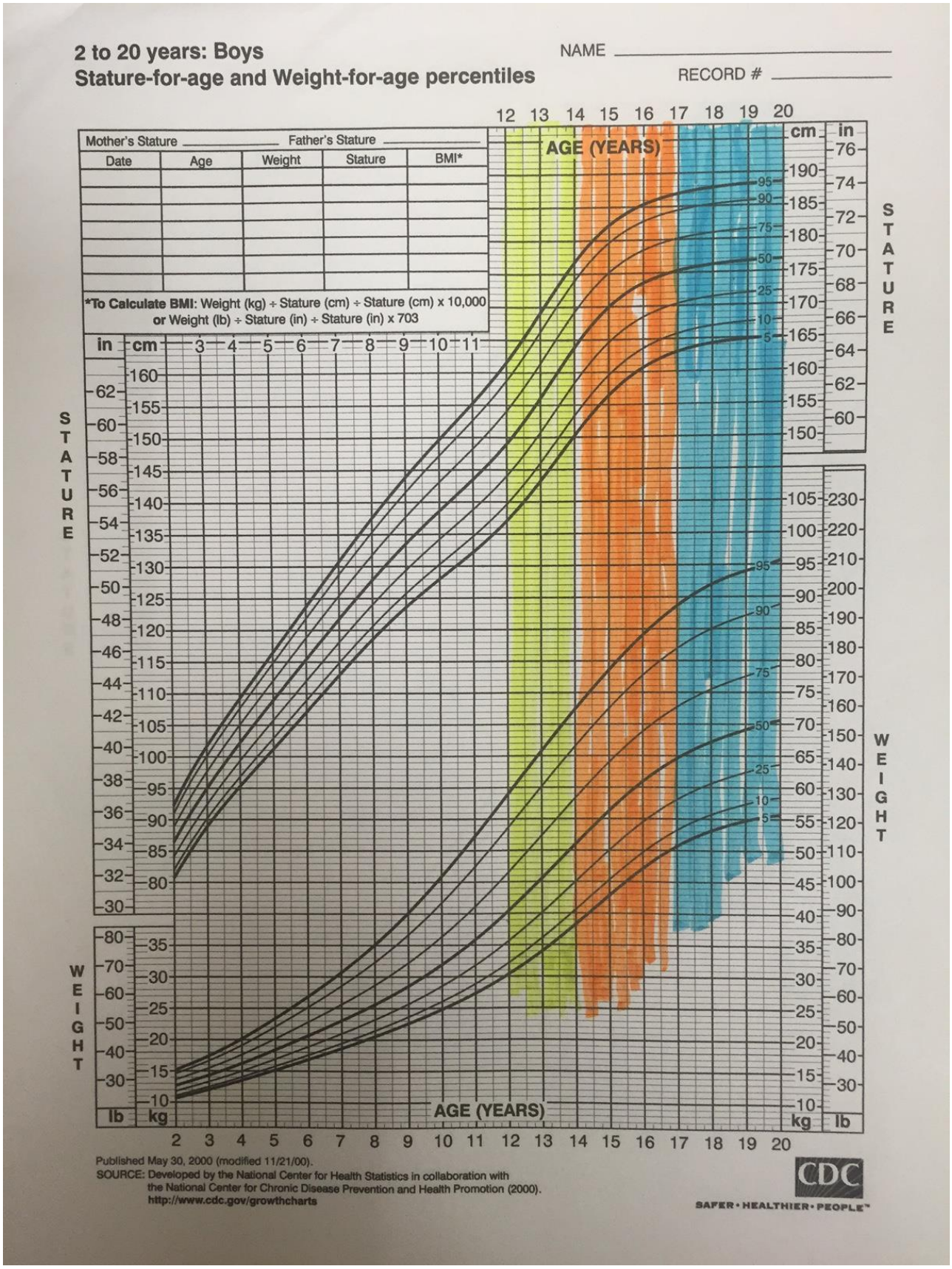
Appendix 8:

1. The Centres for Disease Control and prevention (CDC) values for stature-for-age and weight –for-age percentiles charts for girls 2-20 years.



Legend: Yellow, cadet age group; Orange, junior age group; Blue, senior age group.

2. The Centres for Disease Control and prevention (CDC) values for stature-for-age and weight –for-age percentiles charts for boys 2-20 years.



Legend: Yellow, cadet age group; Orange, junior age group; Blue, senior age group.