Korean Taekwondo Athletes

Subjects: Physics, Particles & Fields
Submitted by: Sang-Seok Nam

Definition

This study aimed to present a standard and normal distribution of Taekwondo athletes' physical characteristics and physical fitness profiles using a systematic review. A systematic search was conducted using four Korean databases (Research Information Sharing Service, National Digital Science Library, DBpia, and Korean Studies Information Service System). From 2010 to 2020, we reviewed 838 papers on Taekwondo athletes' physical characteristics and physical fitness factors (e.g., body composition, muscle strength, muscular endurance, flexibility, cardiorespiratory fitness, power, agility, balance, speed, and reaction time).

1. Introduction

Taekwondo is an international martial arts sport conducted in 210 countries worldwide as an official Olympic sport. A Taekwondo competition occurs in three rounds, with a duration of 2 min per round and a rest duration of 1 min between rounds [1]. Athletes who score more points or knock out their opponent win. During a competition, athletes use powerful and fast kicks and punches on their opponent's trunk and sometimes kicks to the face [2]. These movements are high-intensity anaerobic or aerobic exercises that induce powerful lower-extremity movements [3]. In addition, agility, flexibility, and muscular endurance are required to maintain an excellent performance among Taekwondo athletes [4][5][6]. Therefore, it is necessary to manage physical fitness factors to improve their performance [7]. This can be achieved by accurately evaluating the level of fitness of athletes and setting goals. Athletes need to know their physical characteristics and physical fitness profiles for effective training because high levels of physical fitness can affect their exercise performance [8]. Suppose there is a basis for the standard distribution of physical fitness profiles necessary for the characteristics of sports events. In this case, it can be used to evaluate athletes' fitness levels and set training goals. Although the physical fitness profiles of taekwondo athletes have been well described in the previous studies, no studies have examined the standard distribution of physical fitness [9][10][11].

Heller et al. [9] compared the physical fitness factors of 23 national Taekwondo athletes from the Czech Republic to those of the general public. Meanwhile, Marković [10] divided 13 women from the Croatian national Taekwondo team into medal-winning and non-medal-winning athletes at World Championships or Olympic Games, comparing the physical fitness profiles between them. In addition, Mathunjwa et al. [11] studied the physical characteristics of 36 internationally ranked junior Taekwondo athletes; the physical fitness test results were standardized in z-scores, which were then compared among the athletes. Furthermore, Bridge et al. [12] and da Silva Santos et al. [13] reported the physical characteristics and physical fitness of Taekwondo athletes using a systematic review but did not present any quantitative results.

Previous studies have provided information on the physical characteristics and physical fitness of Taekwondo athletes [12][13]. However, it is difficult to use them as a specific indicator because there is no standard distribution to evaluate the level of physical fitness of Taekwondo athletes. Standard distribution data are needed to determine the mean and percentile values of Taekwondo athletes' physical characteristics and physical fitness parameters. In general, a standard distribution is meaningful when the measurement results of a large sample form a normal distribution [14]. However, it can be analyzed via a systematic review using the measured variables in a previous study [15]. In other words, the results could be interpreted as a normal distribution when the sum of sample sizes is sufficiently large by integrating each previous study [15]. Nevertheless, the validity and reliability of the resulting values can be questioned if different prior studies have different measurement tools. However, the measurement of physical characteristics and physical fitness variables has become common worldwide. Furthermore, the systematic review method can resolve the concerns about reliability and validity by eliminating extreme values when integrating the results of variables [15]. Thus, the standard distribution of physical characteristics and physical fitness factors can be estimated using the pooled mean and pooled standard deviation from previous studies.

The purpose of this study was to present a standard and normal distribution of Taekwondo athletes' physical characteristics and physical fitness profiles using a systematic review.

2. Analysis on Results

For the male Taekwondo athletes, the total sample size in relation to the physical characteristics was 224–430, and the estimated error was ±0.28–2.79%. The estimated error was the smallest height and the largest percentage of body fat. In addition, the estimated error of body mass index (BMI) (n = 224, ±0.89%) was smaller than that of the percentage of body fat (n = 236, ±2.79%).

The estimated values of each grade were calculated by applying the pooled mean and pooled standard deviation for each

physical characteristic to the normal distribution and setting the grade at 10% intervals of cumulative probability. Examples of the estimated values corresponding to the top 10% of each physical characteristic in the study results were as follows: (1) the top 10% for the BMI of the male Taekwondo athletes was 20.0–20.4 kg/m 2; and (2) the top 10% for the percentage of body fat of the female Taekwondo athletes was 18.3–19.8%. The estimated normal distribution and 95% confidence interval of each physical characteristic are listed in **Table 1** .

Table 1. Ninety-five percent confidence intervals for the Taekwondo athletes' physical characteristics.

Sex	Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Male	Height (cm)	95% LV	165.2	168.8	170.7	173.1	174.7	176.2	177.5	178.8	180.3	181.9	184.3	186.2	189.8
		95% UV	166.2	169.8	171.7	174.1	175.7	177.2	178.5	179.8	181.3	182.9	185.3	187.2	190.8
	Weight (kg)	95% LV	43.1	51.2	55.5	60.7	64.4	67.6	70.6	73.6	76.9	80.6	85.8	90.1	98.2
		95% UV	45.3	53.4	57.7	62.9	66.7	69.9	72.9	75.9	79.1	82.8	88.1	92.4	100.4
	Percentage of body fat (%)	95% LV	18.8	16.9	15.9	14.7	13.8	13.0	12.3	11.6	10.9	10.0	8.8	7.8	5.9
		95% UV	19.5	17.6	16.6	15.4	14.5	13.7	13.0	12.3	11.6	10.7	9.5	8.5	6.6
	BMI (kg/m^2)	95% LV	25.5	24.5	23.9	23.2	22.8	22.3	22.0	21.6	21.2	20.7	20.0	19.5	18.5
		95% UV	25.9	24.8	24.3	23.6	23.2	22.7	22.4	22.0	21.6	21.1	20.4	19.9	18.8
Female	Height (cm)	95% LV	154.7	158.4	160.4	162.8	164.5	166.0	167.4	168.8	170.3	172.0	174.4	176.4	180.2
		95% UV	156.8	160.6	162.5	165.0	166.7	168.2	169.6	171.0	172.4	174.2	176.6	178.6	182.3
	Weight (kg)	95% LV	45.5	49.5	51.6	54.2	56.1	57.7	59.1	60.6	62.2	64.1	66.7	68.8	72.8
		95% UV	47.8	51.8	53.9	56.5	58.4	60.0	61.5	63.0	64.5	66.4	69.0	71.1	75.2
	Percentage of body fat (%)	95% LV	30.2	27.9	26.7	25.3	24.3	23.4	22.5	21.7	20.8	19.8	18.3	17.1	14.9
		95% UV	31.6	29.4	28.2	26.7	25.7	24.8	24.0	23.1	22.2	21.2	19.8	18.6	16.3

BMI, body mass index; CI, confidence interval; LV, lower value; and UV, upper value.

The estimated values of each grade were calculated by applying the pooled mean and pooled standard deviation for each physical fitness variable to the normal distribution and setting the grade at 10% intervals of cumulative probability.

Examples of the estimated values corresponding to the top 10% of each physical fitness variable in the study results were as follows: (1) the top 10% for the hand-grip strength of the male Taekwondo athletes was 49.1–51.5 kg; and (2) the top 10% for the VO 2max of the female Taekwondo athletes was 61.2–63.8 mL/kg/min. The estimated normal distribution and 95% confidence interval of each physical fitness variable are listed in **Table 2** .

Table 2. Ninety-five percent confidence intervals for the Taekwondo athletes' physical fitness.

Sex	Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
	Hand-grip strength (kg)	95% LV	33.3	36.3	37.9	39.8	41.2	42.4	43.5	44.6	45.8	47.2	49.1	50.7	53.7
		95% UV	35.7	38.7	40.3	42.2	43.6	44.8	45.9	47.0	48.2	49.5	51.5	53.1	56.0
		95% LV	70.2	83.5	90.7	99.3	105.5	110.8	115.8	120.7	126.1	132.3	140.9	148.0	161.4

Sex	Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Male	Back saver sit and reach (kg)	95% UV	78.9	92.2	99.4	108.0	114.2	119.5	124.5	129.4	134.8	141.0	149.6	156.7	170.1
	Sit-up per 30 s (times)	95% LV	18.9	22.0	23.6	25.6	27.0	28.3	29.4	30.5	31.8	33.2	35.2	36.8	39.9
		95% UV	21.2	24.2	25.9	27.8	29.3	30.5	31.6	32.8	34.0	35.4	37.4	39.0	42.1
	Sit-up per 60 s (times)	95% LV	42.2	46.4	48.6	51.3	53.2	54.9	56.4	57.9	59.6	61.5	64.2	66.4	70.6
		95% UV	44.2	48.4	50.6	53.3	55.2	56.9	58.4	60.0	61.6	63.5	66.2	68.4	72.6
	Sit and reach (cm)	95% LV	−0.1	4.3	6.7	9.6	11.6	13.4	15.1	16.7	18.5	20.5	23.4	25.8	30.2
		95% UV	1.7	6.1	8.5	11.4	13.4	15.2	16.8	18.5	20.3	22.3	25.2	27.6	32.0
	Backward flexion (cm)	95% LV	40.6	45.2	47.7	50.8	52.9	54.8	56.5	58.3	60.1	62.3	65.3	67.8	72.5
		95% UV	44.7	49.4	51.9	54.9	57.1	59.0	60.7	62.4	64.3	66.5	69.5	72.0	76.7
	VO_2max (mL/kg/min)	95% LV	33.7	38.9	41.6	45.0	47.4	49.5	51.4	53.3	55.4	57.8	61.2	63.9	69.1
		95% UV	36.3	41.5	44.3	47.6	50.0	52.1	54.0	56.0	58.0	60.4	63.8	66.6	71.8
	HRmax (bpm)	95% LV	155.6	162.0	165.5	169.7	172.7	175.3	177.7	180.1	182.7	185.7	189.9	193.3	199.8
		95% UV	160.1	166.6	170.0	174.2	177.2	179.8	182.2	184.6	187.2	190.2	194.4	197.9	204.3
	20-m MST (times)	95% LV	80.5	85.0	87.4	90.4	92.5	94.3	95.9	97.6	99.4	101.5	104.4	106.8	111.4
		95% UV	84.1	88.7	91.1	94.0	96.1	97.9	99.6	101.3	103.0	105.2	108.1	110.5	115.0
	Standing long jump (cm)	95% LV	208.5	218.0	223.0	229.1	233.6	237.3	240.8	244.4	248.1	252.5	258.7	263.7	273.2
		95% UV	212.8	222.2	227.3	233.4	237.8	241.6	245.1	248.6	252.4	256.8	262.9	268.0	277.4
	Vertical jump (cm)	95% LV	41.4	45.0	46.9	49.2	50.8	52.3	53.6	54.9	56.3	58.0	60.3	62.2	65.8
		95% UV	43.3	46.9	48.8	51.1	52.7	54.2	55.5	56.8	58.2	59.9	62.2	64.1	67.7
	Whole-body reaction time (light, ms)	95% LV	0.338	0.320	0.310	0.298	0.289	0.282	0.275	0.268	0.261	0.252	0.240	0.231	0.212
		95% UV	0.355	0.336	0.326	0.314	0.306	0.298	0.292	0.285	0.277	0.269	0.257	0.247	0.229
	Whole-body reaction time (sound, ms)	95% LV	0.346	0.324	0.313	0.299	0.288	0.280	0.272	0.263	0.255	0.245	0.230	0.219	0.197
		95% UV	0.363	0.341	0.330	0.315	0.305	0.297	0.288	0.280	0.272	0.261	0.247	0.236	0.214
	Eyes-closed single-leg stance (s)	95% LV	−23.6	−7.8	0.5	10.7	18.0	24.2	30.1	35.9	42.2	49.5	59.6	68.0	83.7
		95% UV	−12.3	3.4	11.7	21.9	29.2	35.5	41.3	47.1	53.4	60.7	70.9	79.2	95.0
	Anaerobic average power	95% LV	340.2	392.1	419.7	453.2	477.3	498.0	517.2	536.5	557.1	581.3	614.8	642.4	694.3
		95% UV	375.1	427.0	454.6	488.1	512.3	532.9	552.2	571.4	592.1	616.2	649.7	677.3	729.2

Sex	Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Male	Peak anaerobic power (relative value, watt/kg)	95% LV	7.8	8.7	9.2	9.8	10.2	10.5	10.9	11.2	11.5	12.0	12.5	13.0	13.9
		95% UV	8.2	9.1	9.6	10.2	10.6	11.0	11.3	11.6	12.0	12.4	13.0	13.4	14.3
	Peak anaerobic power (absolute value, watt)	95% LV	425.7	504.2	546.1	596.7	633.3	664.5	693.7	722.8	754.1	790.6	841.3	883.1	961.6
		95% UV	478.6	557.1	598.9	649.6	686.1	717.3	746.5	775.7	806.9	843.4	894.1	935.9	1014.4
	Peak drop (%)	95% LV	29.2	34.5	37.3	40.8	43.2	45.3	47.3	49.3	51.4	53.9	57.3	60.1	65.4
		95% UV	32.0	37.3	40.1	43.6	46.0	48.1	50.1	52.1	54.2	56.7	60.1	62.9	68.2
	Left knee joint flexion (60°/s, Nm) [a]	95% LV	67.5	83.6	92.2	102.6	110.1	116.5	122.5	128.5	134.9	142.4	152.8	161.4	177.6
		95% UV	77.0	93.2	101.8	112.2	119.7	126.1	132.1	138.1	144.5	152.0	162.4	171.0	187.1
	Left knee joint extension (60°/s, Nm) [a]	95% LV	124.2	146.8	158.9	173.5	184.1	193.1	201.5	210.0	219.0	229.5	244.2	256.3	278.9
		95% UV	137.6	160.3	172.4	187.0	197.5	206.6	215.0	223.4	232.4	243.0	257.6	269.7	292.4
	Right knee joint flexion (60°/s, Nm) [a]	95% LV	69.5	86.1	95.0	105.7	113.4	120.0	126.2	132.4	139.0	146.7	157.4	166.3	182.9
		95% UV	79.4	96.0	104.8	115.6	123.3	129.9	136.1	142.2	148.8	156.6	167.3	176.1	192.7
	Right knee joint extension (60°/s, Nm) [a]	95% LV	132.6	154.6	166.3	180.5	190.7	199.4	207.6	215.8	224.5	234.8	248.9	260.6	282.6
		95% UV	145.6	167.6	179.3	193.5	203.7	212.5	220.7	228.8	237.6	247.8	262.0	273.7	295.7
Female	Sit-up per 60 s (times)	95% LV	36.6	41.2	43.7	46.7	48.9	50.7	52.5	54.2	56.1	58.2	61.2	63.7	68.4
		95% UV	40.0	44.7	47.2	50.2	52.3	54.2	55.9	57.7	59.5	61.7	64.7	67.2	71.8
	Sit and reach (cm)	95% LV	3.8	8.4	10.9	14.0	16.1	18.0	19.7	21.5	23.3	25.5	28.5	31.0	35.7
		95% UV	6.9	11.6	14.1	17.1	19.3	21.2	22.9	24.7	26.5	28.7	31.7	34.2	38.9
	VO_2max (mL/kg/min)	95% LV	33.1	37.0	39.1	41.6	43.4	44.9	46.3	47.8	49.3	51.1	53.6	55.7	59.5
		95% UV	37.0	40.9	42.9	45.4	47.2	48.8	50.2	51.7	53.2	55.0	57.5	59.6	63.4
	20-m MST (times)	95% LV	49.2	57.6	62.0	67.4	71.4	74.7	77.8	80.9	84.3	88.2	93.6	98.1	106.5
		95% UV	55.6	64.0	68.5	73.9	77.8	81.1	84.3	87.4	90.7	94.6	100.1	104.5	112.9
	Standing long jump (cm)	95% LV	155.6	165.3	170.5	176.7	181.3	185.1	188.7	192.3	196.2	200.7	207.0	212.2	221.9
		95% UV	163.1	172.8	177.9	184.2	188.7	192.6	196.2	199.8	203.7	208.2	214.5	219.6	229.4
	Peak anaerobic power (relative value, (watt)	95% LV	6.4	7.1	7.5	8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.3	10.7	11.4
		95% UV	7.0	7.8	8.2	8.6	9.0	9.3	9.5	9.8	10.1	10.4	10.9	11.3	12.1

Sex	watt/kg) Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Female	Peak drop (%)	95% LV	35.9	40.1	42.3	45.0	47.0	48.7	50.2	51.8	53.4	55.4	58.1	60.3	64.5
		95% UV	39.8	44.0	46.2	48.9	50.9	52.6	54.1	55.7	57.3	59.3	62.0	64.2	68.4
	Left knee joint flexion (60°/s, Nm) [a]	95% LV	59.8	69.9	75.3	81.8	86.5	90.5	94.3	98.1	102.1	106.8	113.3	118.7	128.8
		95% UV	66.7	76.8	82.2	88.8	93.5	97.5	101.2	105.0	109.0	113.7	120.3	125.7	135.8
	Left knee joint extension (60°/s, Nm) [a]	95% LV	109.3	126.2	135.2	146.1	154.0	160.7	167.0	173.3	180.0	187.9	198.8	207.8	224.7
		95% UV	120.9	137.8	146.8	157.8	165.6	172.3	178.6	184.9	191.6	199.5	210.4	219.4	236.3
	Right knee joint flexion (60°/s, Nm) [a]	95% LV	56.6	67.4	73.2	80.2	85.3	89.6	93.6	97.7	102.0	107.0	114.1	119.8	130.7
		95% UV	64.1	74.9	80.7	87.7	92.8	97.1	101.1	105.1	109.5	114.5	121.5	127.3	138.2
	Right knee joint extension (60°/s, Nm) [a]	95% LV	101.2	118.7	128.0	139.4	147.5	154.5	161.0	167.5	174.5	182.6	193.9	203.3	220.8
		95% UV	113.2	130.8	140.1	151.4	159.6	166.5	173.0	179.5	186.5	194.7	206.0	215.3	232.8
	Left knee joint flexion (120°/s, Nm) [a]	95% LV	57.5	62.3	64.8	67.9	70.1	72.0	73.7	75.5	77.4	79.6	82.6	85.1	89.9
		95% UV	61.7	66.4	68.9	72.0	74.2	76.1	77.8	79.6	81.5	83.7	86.7	89.3	94.0
	Left knee joint extension (120°/s, Nm) [a]	95% LV	84.3	95.1	100.8	107.8	112.8	117.1	121.1	125.1	129.4	134.5	141.4	147.2	158.0
		95% UV	93.6	104.4	110.2	117.2	122.2	126.5	130.5	134.5	138.8	143.8	150.8	156.5	167.3
	Right knee joint flexion (120°/s, Nm) [a]	95% LV	50.6	56.6	59.8	63.6	66.4	68.8	71.0	73.3	75.6	78.4	82.3	85.5	91.5
		95% UV	55.8	61.8	65.0	68.8	71.6	74.0	76.2	78.4	80.8	83.6	87.5	90.7	96.7
	Right knee joint extension (120°/s, Nm) [a]	95% LV	84.1	94.8	100.4	107.3	112.3	116.5	120.5	124.5	128.7	133.7	140.5	146.2	156.9
		95% UV	93.3	104.0	109.7	116.6	121.5	125.8	129.7	133.7	137.9	142.9	149.8	155.5	166.1
	Left knee joint flexion (240°/s, Nm) [a]	95% LV	38.9	43.9	46.6	49.9	52.2	54.2	56.1	58.0	60.0	62.4	65.6	68.3	73.4
		95% UV	43.3	48.3	51.0	54.3	56.6	58.6	60.5	62.4	64.4	66.7	70.0	72.7	77.7
	Left knee joint extension (240°/s, Nm) [a]	95% LV	59.7	67.8	72.1	77.4	81.1	84.4	87.4	90.4	93.6	97.4	102.6	107.0	115.1
		95% UV	66.7	74.8	79.2	84.4	88.2	91.4	94.4	97.4	100.7	104.4	109.7	114.0	122.1
	Right knee joint flexion (240°/s, Nm) [a]	95% LV	39.8	44.1	46.4	49.2	51.2	52.9	54.5	56.1	57.8	59.8	62.6	64.9	69.2
		95% UV	43.5	47.8	50.1	52.9	54.9	56.6	58.2	59.8	61.5	63.5	66.3	68.6	72.9
		95% LV	60.6	68.4	72.5	77.5	81.2	84.3	87.2	90.0	93.1	96.8	101.8	105.9	113.7
	Right knee joint extension (240°/s, Nm) [a]	95% UV	67.3	75.1	79.3	84.3	87.9	91.0	93.9	96.8	99.9	103.5	108.5	112.7	120.5

Sex	Variables	95% CI	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
Female	Trunk joint flexion (60°/s, Nm) [a]	95% LV	81.9	97.9	106.4	116.8	124.2	130.6	136.5	142.5	148.8	156.3	166.6	175.1	191.1
		95% UV	95.8	111.8	120.3	130.6	138.1	144.4	150.4	156.3	162.7	170.1	180.4	189.0	205.0
	Trunk joint extension (60°/s, Nm) [a]	95% LV	74.9	95.6	106.7	120.0	129.7	137.9	145.6	153.3	161.6	171.2	184.6	195.7	216.4
		95% UV	92.8	113.6	124.6	138.0	147.7	155.9	163.6	171.3	179.6	189.2	202.6	213.6	234.4
	Trunk joint flexion (120°/s, Nm) [a]	95% LV	65.7	85.8	96.5	109.5	118.9	126.9	134.4	141.8	149.8	159.2	172.2	182.9	203.0
		95% UV	83.2	103.3	114.0	127.0	136.3	144.3	151.8	159.3	167.3	176.6	189.6	200.3	220.4
	Trunk joint extension (120°/s, Nm) [a]	95% LV	68.1	87.0	97.1	109.3	118.1	125.7	132.7	139.7	147.3	156.1	168.3	178.4	197.3
		95% UV	84.5	103.4	113.5	125.7	134.6	142.1	149.1	156.2	163.7	172.5	184.7	194.8	213.7

VO_2max, maximal oxygen consumption per minute; HRmax, maximal heart rate per minute; MST, multistage shuttle-run test; CI, confidence interval; LV, lower value; UV, upper value; [a], isokinetic muscular strength.

3. Current Insights

For Taekwondo competitions, athletes must have excellent physical fitness, including aerobic capacity, anaerobic capacity, muscle strength, muscle endurance, flexibility, speed, and agility [9][10][16][17]. In addition, data-based exercise science information is helpful in improving Taekwondo athletes' physical fitness and weakness [6]. Therefore, this study aimed to provide a profile of physical characteristics and physical fitness for Taekwondo competitors. To increase the value of this study's data-based exercise science information, we secured the validity of the estimation results. In a previous study that developed an estimation model of the physical fitness level, the validity of the estimation results was recognized when the estimated error was within 8–10% [18][19][20]. In this study, the estimation error of all variables, except for the eyes-closed single-leg stance (15.71%), was less than 8%. Therefore, it was confirmed that there was no problem with the validity of the estimated values.

The following can be interpreted as the causes of the higher estimation error in the eyes-closed single-leg stance than in the other variables. First, the sample size in relation to the variable was small. The estimation error was calculated by dividing the standard deviation by the square root of the sample size; therefore, the smaller the sample size, the larger the estimation error. However, the total sample size for the eyes-closed single-leg stance was 65, so the sample size was not small compared to that of the other variables. Therefore, this problem is hardly attributable to the increase in the estimation error. Second, there was a large deviation between individuals in the measurement of the variables. The eyes-closed single-leg stance is a variable that shows a large individual difference in measurement. Therefore, the estimation error was calculated based on the eyes-closed single-leg stance data presented in a previous study.

Based on the results of the previous study, the estimated error of the eyes-closed single-leg stance was calculated to be 40.7% for 16 college soccer players (34.0 ± 28.21 s) [21] and 54.6% for 10 high school female volleyball players (59.5 ± 52.4 s) [22]. Therefore, the estimation error increases proportionally because the individual difference between the measurements is large in the eyes-closed single-leg stance test. However, the results of our study have general validity because the estimation error of all variables, except for the eyes-closed single-leg stance, was less than 8%.

The utilization of different measurements that evaluate the same physical fitness factors favoring indicators with small estimation errors may be preferred. However, they should be carefully selected considering the inherent reliability of the measurement methods. For example, selecting BMI should be avoided because it has a smaller estimation error than the percentage of body fat when measuring obesity. The percentage of body fat directly tested using the bioelectrical impedance method was more accurate in obesity assessment than BMI calculated based on height and weight [23][24]. Nevertheless, BMI is being used to assess obesity in the public health and sports fields. The results of this study may be fully utilized for evaluation because the error in the estimated BMI distribution was not significant. For sit-up tests, it is recommended to conduct such for 60 s with a lower estimation error than that for 30 s. Measurements via the same test method and reliability should utilize a distribution with a smaller estimation error. Nevertheless, sit-up tests for 30 s are also available in public health and sports because of the low estimation error.

Combat sports, such as Taekwondo, require high levels of physical fitness and physical characteristics [25]. Exercise program plans are important for improving and maintaining a high level of physical fitness suitable for the characteristics of

Taekwondo events [26]. Taekwondo athletes should be conditioned to effectively manage and improve their physical fitness through systematic exercise programs [27]. Conditioning management requires detailed knowledge of the physiological and physical abilities required for competition [28][29]. Therefore, sports scientists and Taekwondo coaches should organize long-term and short-term training programs and provide objective feedback to motivate athletes. As in this study, objective collection and presentation of information on an athlete's physical ability are important for feedback to the athlete [30]. The results of this study can help identify the physical profiles favorable to Taekwondo competitions and provide indicators of physical fitness standards for Taekwondo athletes [9][10]. This study had limitations. In the study, Korean Taekwondo athletes were considered the study subjects for the systematic search because they have the best performance in the world. However, Taekwondo athlete's skills and performance are becoming similar around the world. Therefore, future studies need to analyze the physical characteristics and physical fitness factors of Taekwondo elite athletes worldwide.

References

1. Janiszewska, K.; Przybyłowicz, K. Pre-competition weight loss among Polish taekwondo competitors–occurrence, methods and health consequences. Arch. Budo 2015, 11, 41–45.
2. Kazemi, M.; Waalen, J.; Morgan, C.; White, A.R. A profile of olympic taekwondo competitors. J. Sports Sci. Med. 2006, 5, 114–121.
3. Kim, H.-B.; Jung, H.-C.; Song, J.-K.; Chai, J.-H.; Lee, E.-J. A follow-up study on the physique, body composition, physical fitness, and isokinetic strength of female collegiate Taekwondo athletes. J. Exerc. Rehabil. 2015, 11, 57–64.
4. Campos, F.A.; Bertuzzi, R.; Dourado, A.C.; Santos, V.G.; Franchini, E. Energy demands in taekwondo athletes during combat simulation. Graefe's Arch. Clin. Exp. Ophthalmol. 2011, 112, 1221–1228.
5. Ball, N.; Nolan, E.; Wheeler, K. Anthropometrical, Physiological, and Tracked Power Profiles of Elite Taekwondo Athletes 9 Weeks before the Olympic Competition Phase. J. Strength Cond. Res. 2011, 25, 2752–2763.
6. Zar, A.; Gilani, A.; Ebrahim, K.; Gorbani, M. A survey of the physical fitness of the male taekwondo athletes of the Iranian national team. Facta Univ. Ser. Phys. Educ. Sport 2008, 6, 21–29.
7. Seo, M.-W.; Jung, H.-C.; Song, J.-K.; Kim, H.-B. Effect of 8 weeks of pre-season training on body composition, physical fitness, anaerobic capacity, and isokinetic muscle strength in male and female collegiate taekwondo athletes. J. Exerc. Rehabil. 2015, 11, 101–107.
8. Andreato, L.V.; Lara, F.J.D.; Andrade, A.; Branco, B.H.M. Physical and Physiological Profiles of Brazilian Jiu-Jitsu Athletes: A Systematic Review. Sports Med. Open 2017, 3, 9.
9. Heller, J.; Peric, T.; Dlouha, R.; Kohlikova, E.; Melichna, J.; Nováková, H. Physiological profiles of male and female taekwon-do (ITF) black belts. J. Sports Sci. 1998, 16, 243–249.
10. Marković, G.; Misigoj-Duraković, M.; Trninić, S. Fitness profile of elite Croatian female taekwondo athletes. Coll. Antropol. 2005, 29, 93–99.
11. Mathunjwa, M.; Mugandani, S.; Djarova-Daniels, T.; Ngcobo, M.; Ivanov, S. Physical, anthropometric and physiological profiles of experienced junior male and female South African Taekwondo athletes. Afr. J. Phys. Health Educ. Recreat. Danc. 2015, 21, 1402–1416.
12. Bridge, C.A.; da Silva Santos, J.F.; Chaabene, H.; Pieter, W.; Franchini, E. Physical and Physiological Profiles of Taekwondo Athletes. Sports Med. 2014, 44, 713–733.
13. da Silva Santos, J.F.; Wilson, V.D.; Herrera-Valenzuela, T.; Machado, F.S.M. Time-Motion Analysis and Physiological Responses to Taekwondo Combat in Juvenile and Adult Athletes: A Systematic Review. Strength Cond. J. 2020, 42, 103–121.
14. Krithikadatta, J. Normal distribution. J. Conserv. Dent. 2014, 17, 96–97.
15. Impellizzeri, F.M.; Bizzini, M. SYSTEMATIC REVIEW AND META-ANALYSIS: A PRIMER. Int. J. Sports Phys. Ther. 2012, 7, 493–503.
16. Pieter, W. Performance characteristics of elite taekwondo athletes. Korean J. Sport Sci. 1991, 3, 94–117.
17. Bouhlel, E.; Jouini, A.; Gmada, N.; Nefzi, A.; Abdallah, K.B.; Tabka, Z. Heart rate and blood lactate responses during Taekwondo training and competition. Sci. Sports 2006, 21, 285–290.
18. Cao, Z.-B.; Miyatake, N.; Higuchi, M.; Ishikawa-Takata, K.; Miyachi, M.; Tabata, I. Prediction of VO2max with daily step counts for Japanese adult women. Graefe's Arch. Clin. Exp. Ophthalmol. 2009, 105, 289–296.
19. McArdle, W.D.; Katch, F.I.; Katch, V.L. Exercise physiology: Nutrition, Energy, and Human Performance. Lippincott Williams & Wilkins: Philadelphia, PA, USA, 2010.
20. Wier, L.T.; Jackson, A.S.; Ayers, G.W.; Arenare, B. Nonexercise models for estimating VO2max with waist girth, percent fat, or BMI. Med. Sci. Sports Exerc. 2006, 38, 555–561.
21. Chun, S.-Y. Comparative of Angle of Calcaneus, Balance, Circumference of Calf and Isokinetic Strength of Ankle on Athletic Performances in Soccer Players. Korean J. Sports Sci. 2015, 24, 1101–1110.
22. Choi, D.-S.; Park, M.-H.; Kim, Y.-Y.; Kim, J.-G.; Chae, W.-S. Effects of 12-week core exercise program on isokinetic muscular function, balance and basic physical fitness of female high school volleyball players. Korean J. Sports Sci. 2019, 28, 1251–1263.
23. Park, E. Overestimation and Underestimation: Adolescents' Weight Perception in Comparison to BMI-Based Weight Status and How It Varies Across Socio-Demographic Factors. J. Sch. Health 2011, 81, 57–64.
24. Provencher, M.T.; Chahla, J.; Sanchez, G.; Cinque, M.E.; Kennedy, N.I.; Whalen, J.; Price, M.D.; Moatshe, G.; LaPrade, R.F. Body Mass Index Versus Body Fat Percentage in Prospective National Football League Athletes: Overestimation of Obesity Rate in Athletes at the National Football League Scouting Combine. J. Strength Cond. Res. 2018, 32, 1013–1019.
25. Chiodo, S.; Tessitore, A.; Lupo, C.; Ammendolia, A.; Cortis, C.; Capranica, L. Effects of official youth taekwondo competitions on jump and strength performance. Eur. J. Sport Sci. 2012, 12, 113–120.
26. Bridge, C.A.; Jones, M.A.; Hitchen, P.; Sanchez, X. Heart rate responses to Taekwondo training in experienced practitioners. J. Strength Cond. Res. 2007, 21, 718.
27. Ke-tien, Y. Training periodization in lower limb performance and neuromuscular controlling in taekwondo athletes. Life Sci. J. 2012, 9, 850–857.
28. Bridge, C.A.; Jones, M.A.; Drust, B. Physiological Responses and Perceived Exertion during International Taekwondo Competition. Int. J. Sports Physiol. Perform. 2009, 4, 485–493.
29. Casolino, E.; Cortis, C.; Lupo, C.; Chiodo, S.; Minganti, C.; Capranica, L. Physiological Versus Psychological Evaluation in Taekwondo Elite Athletes. Int. J. Sports Physiol. Perform. 2012, 7, 322–331.

30. Kim, H.-B.; Stebbins, C.L.; Chai, J.-H.; Song, J.-K. Taekwondo training and fitness in female adolescents. J. Sports Sci. 2011, 29, 133–138.

Keywords

taekwondo;physical characteristics;physical fitness;systematic review;normal distribution