ORIGINAL ARTICLE

Weight distribution in karate stances: a comparison between experimental and postulated values

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Abstract

Background & Study Aim: Karate is a highly popular Japanese martial art that uses a variety of stances during its practice. These stances play a significant role in the effectiveness of the karate techniques. In this context, the objective of this study is to verify whether the weight distribution in these stances corroborates with the postulated values presented in the literature.

Material & Methods: The weight distribution on the lower limbs of three shotokan karate stances: back (*kokutsu-dachi*), front (*zenkutsu-dachi*), and horseman stance (*kiba-dachi*), were acquired by force plate for nine male black belts (age: mean 46.78 ±9.7 years; mass: 85.88 ±6.31 kg; height: 1.76 ±0.03 m; experience: 31.56 ±8.5 years). The weight distributions were statistically compared to the values presented in the literature by the bootstrap-*t* confidence interval method to test whether the experimental values differs from postulated values.

Results: The weight distributions for the three stances did not present a significant difference between the population mean and the postulated values in the weight distributions, at 0.05 of probability.

Conclusions: These results indicate that the experimental values for the weight distribution corroborate with empirical values postulated in the specialized literature.

Keywords: bootstrap-*t* confidence interval method · *kiba-dachi* · *kokutsu-dachi* · martial arts · weight distribution · *zenkutsu-dachi*

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Karate stance – in this word connectios the term "**stance**" is not straight synonym of the term "**posture**"

Introduction

The karate stances play a crucial role in the effectiveness of the techniques used in sportive competitions, as has been emphasized both in the early literature of the genre, e.g., the works of Nakayama [1], Funakoshi [2] and Nishiyama [3] and also in the recent works like in Vences Brito et. al. [4]. The development of sense of balance in karate, which is coordinated with a set of complex motor skills, is developed through training, which involves the practice of a wide variety of stances.

These karate stances are categorized according to the weight distribution on the lower limbs, the knee position in relation to the foot, and the distance between the feet. Obviously, some stances have a higher incidence in practice and competition than others. Indeed, the back stance (*kokutsu-dachi*), the front stance (*zenkutsu-dachi*), and the horseman stance (*kiba-dachi*) are by far the most common stances during both practice and competition [5].

The effect of the weight distribution on these stances is known to have a significant effect on the karate techniques. The weight distribution on the lower limbs has been shown to affect the impulse and the attack-time of the arm techniques [6, 7], both of which are important variables when evaluating effectiveness. Despite its importance in the effective execution of Karate techniques, the values cited by Nakayama, Funakoshi and Nishiyama were based on practical experience, and no mechanical study has been done to determine the values. Additionally, the weight distribution on two these stances still a matter of controversy among martial artists, authors and researchers [8].

It should be pointed out that the difference in the weight distributions of each of three stances is distinct, as their names suggest. The weight distribution in the back stance (*kokutsu-dachi*) is traditionally postulated as 70% on the rear and 30% on the front leg, corroborated in famous works on the subject like Nakayama [1, 10, 11], Nishiyama [3],Tagnini [9], Kanazawa [12] and Doder et al. [13]. However, this distribution is disputed by several experts in the field as attested in the works of Jorga et al. [14] and Donovan [15].

The weight distribution in the front stance (*zenkutsu-dachi*) is postulated as 60% on the front and 40% on the rear leg, as indicated in the works of Nakayama [1, 10, 11], Nishiyama [3] Tagnini [9] and Kanazawa [12] corroborated by scientific papers by Stull et al. [16], Doder et al. [17] and Doder et al. [18]. This weight distribution is disputed by Loczi [19] who claims that the weight is almost evenly distributed, and Liu et al. [6] who reported a weight distribution between 63% to 77% on the front and 37% to 23% on the rear leg. In the case of the last stance, i.e., the horseman stance (*kiba-dachi*) the experts are in consensus: each leg supports 50% of the weight as indicated by Doder et al. [20].

Apart from Liu et al. [6] Wang et al. [7] and Loczi [19] there have been few studies reported on the weight distribution for these Karate stances. It should be noted that some discussions considered pioneering literature in the field, including the classic texts of Nakayama [1, 10, 11], Tagnini [9], Funakoshi [2], Nishiyama and Brown [3] and Kanazawa [12], do not exhibit the consistency and rigor of the scientific method.

In this context, the objective of this study is to verify whether the weight distribution in these stances corroborates with the postulated values presented in the literature by formulating a hypothesis test through the bootstrap-*t* confidence interval method.

Material and methods

Subjects

Nine healthy male volunteers (age: 46.78 ±9.7 years; mass: 85.88 ± 16.31 kg; height: 1.76 ± 0.03 meter; experience: 31.56 ± 8.5 years; mean ± SD), all black belts practitioners under the approval of the Santa Catarina State University ethics committee. The descriptive anthropometric measure of all subjects in this study is presented in the Table 1.

Since all subjects were experienced practitioners of Shotokan Karate, with an average experience of 31.56 ±8.5 years, it was assumed that the subjects can perform the tasks involved in this study in a highly standardized way. Two subjects (4 and 5) have higher than average the variable weight, which is directly connected to the measure of interest in this study (weight distribution on the lower limbs), suggesting that this variable may present a skewed distribution.

Apparatus and experimental protocol

The subjects statistically performed three Karate stances on two force plates (model OR6-GT, Advanced Mechanical Technology, Inc.-AMTI, USA) for 5 s with 10 s between each stance at a sampling rate of 2000 Hz. Figure 1 illustrates the three stances analyzed in this study: back stance (Figure 1a), front stance (Figure 1b) and horseman stance

Table 1. Descriptive anthropometric measures for the subjects

Subject	Age [years]	Height [m]	Weigth [kg]	Experience [years]
1	58	1.82	76.40	40
2	34	1.78	84.60	22
3	42	1.76	78.70	31
4	52	1.75	122.00	38
5	35	1.72	96.70	20
6	53	1.78	63.50	25
7	45	1.73	78.10	38
8	61	1.75	88.30	43
9	41	1.73	84.30	27
Average±sd	46.78±9.7	1.76±0.03	85.88±16.31	31.56±8.5

(Figure 1c). The force plate control and data acquisition was conducted by the commercial package NetForce (version 2.4.0).

Data collection

All force and moment components of each stance were acquired, i.e., the three components of the reaction force, (here denoted as F_x, F_y and F_z), and the three components moment (here denoted as M_x, M_y, and M_z), but in this article only the vertical component F_z is discussed. Finally, all signals acquired were filtered employing a low-pass filter (Hamming window) with a cut-off frequency of ten (10) Hz. The cut-off frequency was decided based on the residual analysis as described by Winter [21].

Statistical analysis

The analysis of the experimental data acquired in this study is conducted by a hypothesis test. This common statistical method is performed by constructing a confidence interval for the mean sample, and then checking whether or not the null postulated value falls within this interval.

This study opts for the confidence bootstrap-*t* interval, to verify whether or not the experimental values for the weight distribution on the three stances (the back, the front and the horseman stances) are in the respective intervals postulated in the specialized literature.

The standard confidence interval for a mean is traditionally provided by

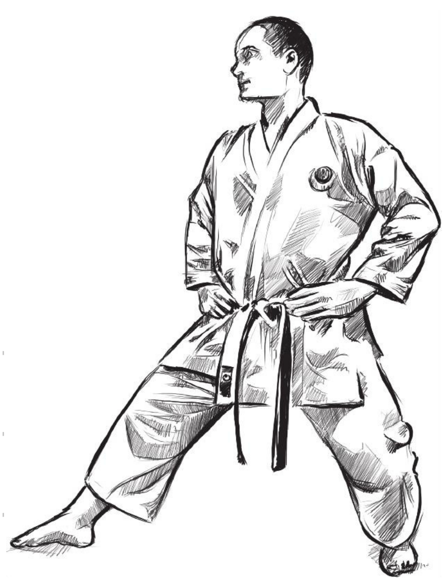

Figure 1 (a). Back stance (*kokutsu-dachi*)

Figure 1 (b). Front stance (*zenkutsu-dachi*)

Figure 1 (c). Horseman stance (*kiba-dachi*)

$$[\hat{\theta} - Z^{(1-\alpha)}.se, \hat{\theta} - Z^{(\alpha)}.se] \quad (1)$$

Where is the sample mean, is the degree of significance to the test, and *se* is the mean standard error. Additionally, *Z* is derived from the assumption that

$$Z = \frac{\hat{\theta} - \theta}{se} \approx N(0,1) \quad (2)$$

This is valid when , but it can be approximated for small samples through

$$Z = \frac{\hat{\theta} - \theta}{se} \approx t_{n-1} \quad (3)$$

Where is the statistic extracted from Student's *t* distribution with degrees of freedom. From equation 3 the confidence interval expressed in equation 1 can be rewritten as

$$[\hat{\theta} - t_{n-1}^{(1-\alpha)}.se, \hat{\theta} - t_{n-1}^{(\alpha)}.se] \quad (4)$$

With representing the th percentile of the *t* distribution. The bootstrap-*t* confidence interval introduced by Efron et al. [22] is derived from equation 4 and is expressed by equation 7. The major advantage of this method is that the confidence intervals generated are more accurate than the standard confidence intervals obtained using sample variance, and asymptotic approximation, and assumption of normality like in equation 2 [23]. Additionally, this method is particularly more accurate for small samples, i.e., where the samples , like the data set employed in this work.

The method estimates the distribution of *Z* directly from the data set, whose tabulated critical values for inference are appropriate for the data collected by experimental research at hand. In this study, 1,000 bootstrap samples, were generated, and for each the following was calculated

$$Z(b) = \frac{\hat{\theta}^*(b) - \theta}{se^*(b)} \quad (5)$$

where is the value of for the bootstrap sample and is the bootstrap standard error. The th percentile of the was estimated by the value of which satisfies

$$\frac{\#\{\hat{t}^{(\alpha)} \geq Z^*(b)\}}{N} = \alpha \quad (6)$$

where # is the number of times that the condition into keys is implemented during the procedure. Consequently, the bootstrap-*t* confidence interval is given by

$$[\hat{\theta} - \hat{t}_{n-1}^{(1-\alpha)}.se, \hat{\theta} - \hat{t}_{n-1}^{(\alpha)}.se] \quad (7)$$

All tests were performed employing the R software [24] with a confidence interval of 0.95. This confidence interval is hereafter noted as . The statistical analysis aims to determine whether or not the sample values of the weight distribution in the three stances differ from the postulated values on the population. The hypothesis of this study is that there is no significant discrepancy between the weight distributions in the three karate stances, presented in section *Apparatus and experimental protocol*, when compared to values postulated by the specialized literature.

Results

This study employed a traditional known method as Q-Q plot to evaluate the normality of the acquired data through identifying outliers and the skewness on the observations, and consequently choose an adequate statistical treatment. Figure 2 presents the Q-Q plots of the weight distributions on the back and front leg for back, front and horseman stances, respectively.

The graphs present a solid line with inclination of 45^0 to compare the traditional Gaussian distribution (horizontal axis) to the acquired data (vertical axis) where points fitting this line indicate the normality of the data. Additionally, the dotted lines graphically represent a 0.95 confidence interval for theoretical quantile of a normal distribution designed to identify the eventual outliers of the data.

Figures 2a, 2b, 2d indicate that the sample data is well behaved and closely approximates a normal distribution. On the other hand, the Figures 2c, 2f and 2e indicate the occurrence of some outliers which can result in a skewed distribution. The circumstances involved in this study, i.e., the small samples, with a strong indication of skewness, corroborates the use of the bootstrap-*t* method to infer the population mean, as stressed in section *Statistical analysis*.

The experimental results and descriptive measures (the mean and the median), for the back, front and horseman stances are provided in the Tables 2, 3 and 4, respectively. It is important to emphasize that the mean of the weight, expressed in Newtons ([N]), is the variable of interest in this study, and it is discriminated by leg into these tables.

The deviations/differences observed between the median and the mean, for both legs in the back, front and horseman stances, are strong indicators of asymmetry in the sample data. The asymmetries are identified by comparing the mean and the median. These

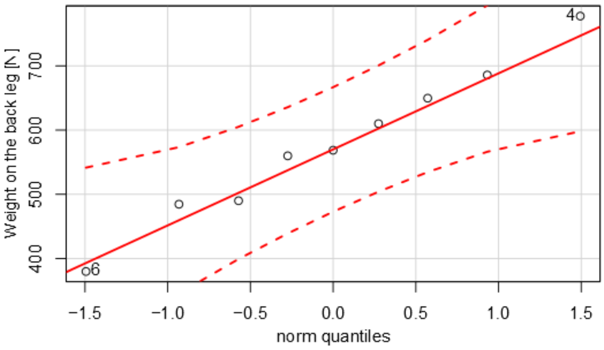

Figure 2 (a). Q-Q plot for the rear leg of the back stance

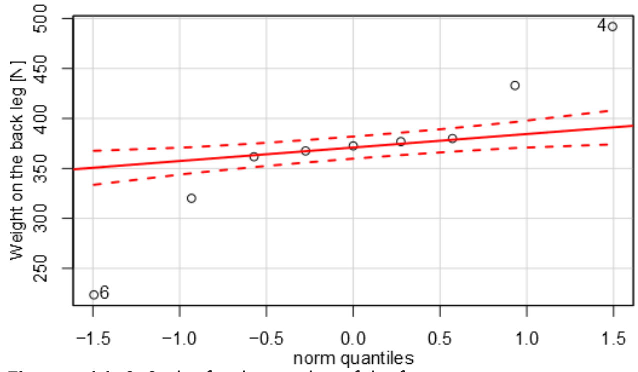

Figure 2 (c). Q-Q plot for the rear leg of the front stance.

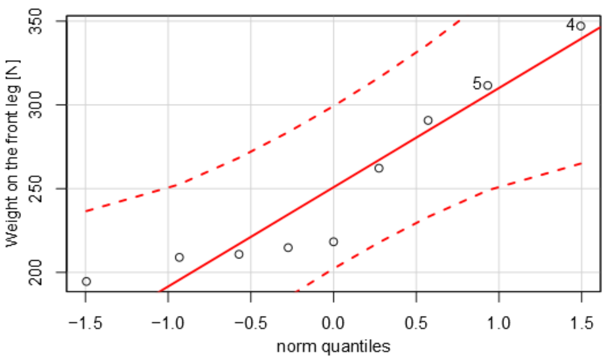

Figure 2 (b). Q-Q plot for the front leg of the back stance

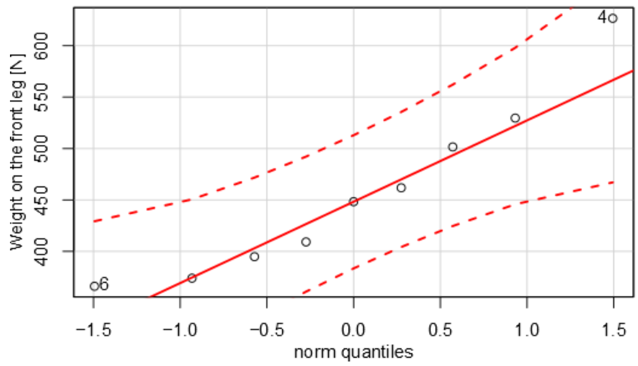

Figure 2 (d). Q-Q plot for the front leg of the front stance.

differences may indicate the occurrence of outliers in the sample data, as shown in the plots above (Figures 2c, 2d and 2f).

The postulated values for the variable of interest and the calculated bootstrap-t confidence interval for the back, front and horseman stances (rear and front legs) are indicated in Tables 5, 6, and 7. The results in Table 5, indicate that the experimental mean for the rear leg in the back stance (580.64 N) is contained in the bootstrap-t confidence interval (495.30 N; 671.90 N). Similarly, the experimental mean for the front leg in the back stance (248.85 N) is contained in the bootstrap-*t* confidence interval (216.20 N; 315.60 N). No evidence was found to indicate a significant difference between the population mean and the postulated values in the weight distributions in the back stance, a 0.05 of probability.

It can be inferred from Table 6 that the experimental mean for the rear leg in the front stance (330.64 N) is contained in the bootstrap-*t* confidence interval (312.00 N; 421.20 N). Similarly, the experimental mean for the front leg in the front stance (495.96 N) is contained in the bootstrap-*t* confidence interval (400.60 N; 543.60 N). As was found in the case of the back stance, the front stance results also present no

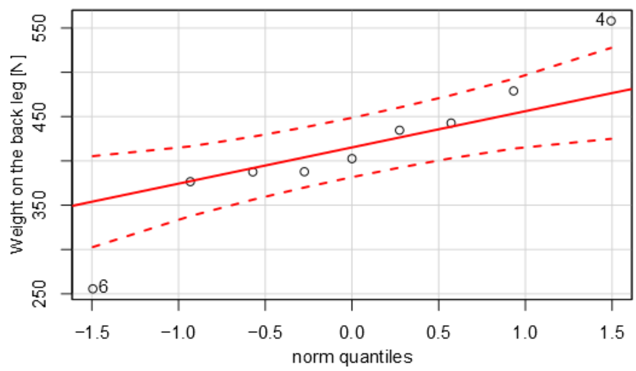

Figure 2 (e). Q-Q plot for the rear leg of the horseman stance.

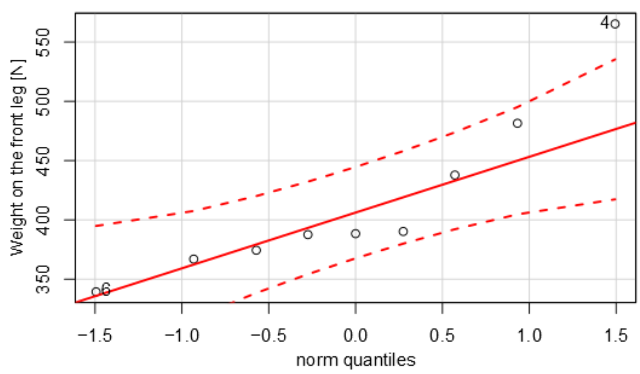

Figure 2 (f). Q-Q plot for the front leg of the horseman stance.

Table 2. Experimental values for the weight distribution in the back stance

	Experimental force [N]		
Subject	Rear leg	Front leg	Weigth [N]
1	490.00	262.21	752.21
2	610.03	214.79	824.82
3	559.93	210.84	770.77
4	777.48	347.13	1124.61
5	649.70	311.64	961.35
6	379.86	218.30	598.17
7	484.60	290.78	775.38
8	685.77	194.60	880.38
9	568.65	209.00	777.65
Mean	578.45	251.04	829.49
Median	568.65	218.31	777.26

Table 3. Experimental values for the weight distribution in the front stance

	Experimental force [N]		
Subject	Rear leg	Front leg	Weigth [N]
1	372.61	373.91	746.52
2	361.74	461.81	823.55
3	376.84	394.84	771.68
4	491.98	626.60	1118.59
5	433.03	529.63	962.66
6	223.57	366.07	589.64
7	367.55	409.18	776.73
8	379.98	501.54	881.52
9	320.13	448.33	768.45
Mean	369.71	456.88	826.59
Median	372.61	448.33	776.73

Table 4. Experimental values for the weight distribution in the horseman stance

	Experimental force [N]		
Subject	Rear leg	Front leg	Weigth [N]
1	376.60	374.43	751.03
2	434.63	390.26	824.89
3	402.57	366.97	769.54
4	557.99	565.29	1123.27
5	478.99	481.51	960.50
6	255.64	339.35	594.99
7	387.82	387.61	775.43
8	442.75	437.84	880.60
9	387.60	388.42	776.03
Mean	413.84	414.63	828.47
Median	402.57	388.42	776.03

Table 5. Postulated values and 95% bootstrap-t confidence interval for the weigth distribution in the back stance

	Postulated force [N]	
Subject	Rear leg	Front leg
1	526.55	225.67
2	577.38	247.45
3	539.54	231.23
4	787.23	337.38
5	672.95	288.41
6	418.72	179.45
7	542.77	232.62
8	616.27	264.11
9	544.36	233.30
Mean	580.64	248.85
$CI95\%_{boot}$	495.30; 671.90	216.20; 315.60

evidence to indicate a significant difference between the population mean and the postulated values in the weight distributions, at 0.05 of probability.

It can be seen from Table 4 that the experimental mean for the rear leg in the horseman stance (413.24 N) is contained in the bootstrap-*t* confidence interval (349.80 N; 477.00 N). Similarly, the experimental mean for the front leg in the horseman stance (414.63 N) is contained in the bootstrap-t confidence interval (372.90 N; 515.70 N). Again, the results for the horseman stance present no evidence to indicate a significant difference between the population mean and the postulated values in the weight distributions, at 0.05 of probability.

Discussion

The stances employed during karate practice play a critical role on the techniques efficiency. In this panorama, this study investigated the weight distribution in three highly-incident karate stances on a sample of experienced karate practitioners. The experimental values were compared to the postulated values found in the specialized literature by formulating a hypothesis test through a bootstrap-*t* confidence

Table 6. Postulated values and 95% bootstrap-t confidence interval for the weigth distribution in the front stance

	Postulated force [N]	
Subject	Rear leg	Front leg
1	375.52	447.91
2	412.44	494.13
3	384.77	463.01
4	561.64	671.15
5	480.25	577.59
6	297.49	353.78
7	387.71	466.04
8	440.30	528.91
9	388.01	461.07
Mean	414.24	495.96
$CI95\%_{boot}$	312.00; 421.20	400.60; 543.60

Table 7. Postulated values and 95% bootstrap-t confidence interval for the weigth distribution in the horseman stance

	Postulated force [N]	
Subject	Rear leg	Front leg
1	375.52	375.52
2	412.44	412.44
3	384.77	384.77
4	561.64	561.64
5	480.25	480.25
6	297.49	297.49
7	387.71	387.71
8	440.30	440.30
9	388.01	388.01
Mean	414.24	414.24
$CI95\%_{boot}$	349.80; 477.00	372.90; 515.70

interval method. The objective of this study is to identify whether or not differences can be found between experimental and postulated pratical values for the weight distributions in these stances.

No statistically significant difference in the experimental weight distribution in the back stance (*kokutsu-dachi*) was found from the postulated values in the literature. Results for the back stance (*kokutsu-dachi*) presents weight distribution of 69.74% on the rear and 30.26% on the front leg, which corroborates with works of Nakayama [1, 10, 11], Tagnini [9], Nishiyama [3], Kanazawa [12] and Doder et al. [13].

The same was observed for the front stance (*zenkutsu-dachi*): the experimental weight distributions are not statistically significant different from the empirical values postulated in the literature. Results indicate a weight distribution of 55.27% on the front and 44.73% on the rear leg. These results are consistent with of Nakayama [1, 10, 11], Tagnini [9], Nishiyama [3], Kanazawa [12], Stull et al. [16], Doder et al. [17] and Doder et al. [18] who presented weight distribution values of 60% and 40% for this stance. Although these values are disputed by Liu et al. [6] and Loczi [19] the differences found may attributed to individual differences among subjects.

Similarly, the experimental weight distributions for the horseman stance (*kiba-dachi*) are not statistically significant different from the empirical values postulated in the literature. Results indicate a weight distribution of 49.95% on the rear and 50.05% on the front leg which also corroborates with the works of Nakayama [1, 10, 11], Tagnini [9], Nishiyama [3], Doder et al. [20], and Kanazawa [12]. Since this stance adopts an evenly distributed posture, i.e. the weight is distributed evenly on the rear and front leg, individual preferences and adjustments are not critical.

Despite the results, the limitations of the current study must be acknowledged. First, the number of highly trained and experienced athletes able to participate in the study was considerably small, and the accuracy of the findings may be compromised because the sample studied. Even so, the statistical treatment, i.e., the bootstrap-*t* confidence interval method decreases this effect. Second, it is impossible to guarantee that individual differences caused by bad practice or individual adjustments on the stances affect the results of the weight distribution. Finally, the weight distribution for the three stances is particular to the shotokan karate style and does not represent postulated values by other styles. Therefore, a further study with a larger population including not only shotokan practitioners is strongly recommended.

Conclusion

The results obtained by formulating a hypothesis test for the mean of the population and calculating a bootstrap-*t* confidence interval, indicate that the evidence, at 0.05 of probability confirm our main hypothesis, i.e. there is no significant difference between the values derived from practical experience postulated in the literature of shotokan karate and their population values (shotokan karate practitioners) for the three karate stances studied.

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Competing interests

Authors declare no conflicts of interest.

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