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Measurement Accuracy of Hand Dynamometers Used for Physical Fitness Testing

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Abstract

The present study was conducted as a field survey to determine the actual degree of hand dynamometer validation performed in schools. The investigation consisted of a questionnaire survey of 43 schools (12 elementary, 6 junior high, and 25 senior high schools) that participated in a workshop for faculty members in the departments of health and physical education, together with actual validation tests for hand dynamometers in 7 of 43 schools (2 public elementary schools and 5 junior high schools), all 7 of which agreed to the testing. The dynamometer validation device of Takei Scientific Instruments Co., Ltd., was used for this study. The questionnaire responses indicated that 5 (12%) of 43 schools had performed hand dynamometer validation and 38 (88%) had not. Although this survey was small in scale, this finding suggests that many schools in Japan do not perform hand dynamometer validation, for various reasons. In the present study, in which an error of ±2.5 kg or more was considered large, the maximum deviation from the reference value was +8.0 kg in a hand dynamometer that showed a mean error of +6.5 kg in the test range of 10-70 kg. The present study has highlighted the issues associated with hand dynamometers used in physical fitness tests. It will be necessary in the future for teachers to raise consciousness about the validation testing of hand dynamometers in schools.

key words: hand dynamometer; measurement accuracy; validation

Purpose

The report on physical fitness of Japanese youth (6 to 19 years of age), issued by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2009, indicated the emergence of a slightly increasing trend in physical fitness on a nationwide level, although it was still below the peaks recorded in 1985 for boys and girls[1]. The report also showed that physical fitness differed greatly depending on the presence or absence of regular exercise, which is also known to have a strong influence on the occurrence of obesity[2-5].

In the test methodology for comprehensive evaluation of physical fitness adopted in Japan in 1999, and in various other tests, the devices used for direct measurements include stopwatches, seated body anteflexion meters, vertical jump meters, and hand dynamometers.

The accuracy of hand dynamometers in particular is known to decline with frequent use, and in the national survey on physical fitness, MEXT directed that measuring devices be properly adjusted and measurement methods be properly implemented and accurately performed[1]. The same concept applies to schools not subject to the national survey guidelines. It is not clear, however, whether validation of hand dynamometers used in the physical fitness tests is regularly performed at general elementary, secondary, and tertiary

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schools.

The present study was conducted as a field survey to determine the actual degree of hand dynamometer validation performed at public elementary and junior high schools.

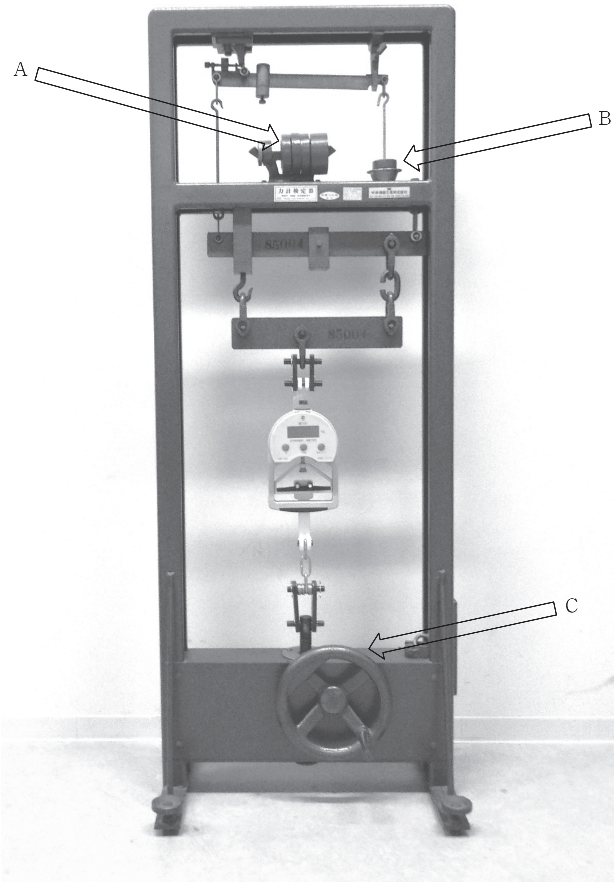

Figure 1 Calibration device

Methods

1. Objects of investigation

The investigation consisted of a questionnaire survey of 43 schools (12 elementary, 6 junior high, and 25 senior high schools) that participated in a workshop for faculty members in the departments of health and physical education, together with actual validation tests for hand dynamometers in 7 of 43 schools (2 public elementary schools and 5 junior high schools), all 7 of which agreed to the testing. Thus, we chose only the schools from which we had obtained agreement.

2. Questionnaire survey on hand dynamometers

The questionnaire items in this survey centered on: 1) whether physical fitness tests were done; and 2) the time of purchase of hand dynamometers, their state of validation, and reasons for non-validation. Faculty members in the departments of health and physical education were asked to complete the questionnaire.

3. Hand dynamometer validation

Validation testing was performed for 30 hand dynamometers in 2 public elementary schools and 5 junior high schools that had not themselves implemented validation of their hand dynamometers but agreed to its performance in this study. The dynamometer validation device of Takei Scientific Instruments Co., Ltd., was used for this purpose (Figure 1).

In the validation test, we first placed weights (Figure 1, A) with certified values of 10 kg to 70 kg in 10-kg increments on the scale pan of the dynamometer validation device as the reference values, then rotated its hand wheel (Figure 1, C) to apply force to the dynamometer hand grip, and determined the difference from the reference value.

At least 2 or 3 trials were performed at each reference level. The mean of 2 stable trials was used as the measured value, and its divergence from the reference value was used as the measurement error. The generally recognized accuracy of spring-type hand dynamometers is ±2.0 kg. All but 2 (thus, 28) of the hand dynamometers tested in this study were spring-type, and any divergence of ± 2.5 kg or more from the reference value was therefore deemed to be a large error.

Figure 2 shows a typical correlation between calibration test values obtained in 2 trials (the first and second) for one of the hand dynamometers. The high reliability of the test is shown by its correlation coefficient of $r^2 = 0.998$ ($p < 0.01$). The reliability of all test values obtained in this study was the same as shown in Figure 2.

4. Measurement period

May 2009 to August 2009

5. Statistical analysis

The reliability of the 2 stable measurement values was tested by Pearson's product-moment correlation coefficient. The compensation formula was constructed with Y as the reference value (10-70 kg) and X as the measured value. The statistical level of significance was less than 5%.

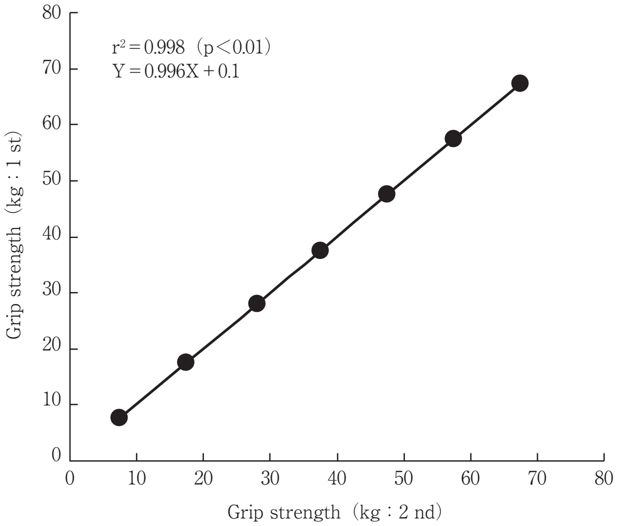

Figure 2 Reliability of certification values

Results

The questionnaire responses indicated that 39 (91%) of 43 surveyed schools conducted physical fitness testing and the remaining 4 (9%) did not. The reasons given for non-testing included problems such as 1) an inability to provide a proper measurement environment due to insufficient budget allocations and 2) avoidance of an influence of such testing on the progress of course work under the course revisions necessitated by changes in government curriculum guidelines.

Only 5 of 43 schools (12%) indicated in the questionnaire responses that they conducted validation testing of their hand dynamometers, and 38 schools (88%) indicated that they did not. The reasons given for non-performance included problems such as 1) lack of budget allocation, 2) insufficient time for preparation and performance due to busy schedules despite awareness of the need, and 3) insufficient knowledge of the method of validation despite awareness of the need.

Table 1 shows the differences found between the reference values and the measured values of 30 hand dynamometers at 7 schools. At one school (School F), the No. 1 and No. 2 hand dynamometers were used for young children, and the validation was therefore performed only up to 60 kg. Manufacturers present the hand dynamometers as uniformly accurate to within 2.0 kg. In the present study, a difference of 2.5 kg or more was assumed to be an error, as is emphasized in gray in Table 1. The errors found in the validation tests ranged up to a maximum of 8.0 kg (error rate: 40%, E-1). Three different tendencies were found in hand dynamometer errors: 1) non-uniform variation in error size among the reference values, 2) emergence of errors only above a certain reference value, and 3) uniform errors over a certain range of reference values. Within the uniform-error range, the error rate tended to increase with decreasing standard weights (Table 1, E-1). Only 16 (53%) of the hand dynamometers consistently showed errors of 2.0 kg or less, and thus were not in need of adjustment.

Discussion

The reports by MEXT on its surveys of physical fitness and exercise capability include classification of results by student age and sex and changes in results as students get older[1]. These reports enable comparisons of changes in physical fitness and motor ability with the progression of student age, comparisons of results for a given age group in different periods, and determination of differences between girls and boys. The reports provide basic information related to the state of student health and the formulation of exercise programs.

It has been reported that, in the results of the physical fitness and motor ability tests, grip strength shows a close correlation with VO_2max, maximum anaerobic power, leg extension power[6], muscle strength other than grip strength[7], and limb muscle mass[6,8]. In short, it is recognized that

Table 1 Difference between criterion value and hand dynamometer certification value.

School	No.	Criterion weight														Measurement system/ indication
		10 kg		20 kg		30 kg		40 kg		50 kg		60 kg		70 kg		
		Error		Error		Error		Error		Error		Error		Error		
		kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	
A	1	−0.5	−5.0	0.5	2.5	0.5	1.7	1.0	2.5	1.0	2.0	1.0	1.7	0.5	0.7	SP/A
	2	−3.0	−30.0	−3.0	−15.0	−2.5	−8.3	−2.5	−6.3	−1.5	−3.0	−3.5	−5.8	−1.0	−1.4	SP/A
B	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.0	SP/A
	2	0.0	0.0	1.0	5.0	1.5	5.0	1.0	2.5	1.5	3.0	1.5	2.5	2.0	2.9	SP/A
C	1	3.0	30.0	1.8	9.0	1.3	4.3	1.0	2.5	1.0	2.0	0.8	1.3	0.3	0.4	SP/A
	2	2.5	25.0	1.8	9.0	1.0	3.3	0.5	1.3	0.0	0.0	−0.5	−0.5	−1.5	−2.1	SP/A
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.2	−0.3	SP/A
	4	2.5	25.0	2.5	12.5	2.5	8.3	1.5	3.8	1.3	2.6	0.3	0.5	0.5	0.7	SP/A
	5	1.0	10.0	1.0	5.0	1.0	3.3	1.0	2.5	0.5	1.0	−0.2	−0.3	−1.0	−1.4	SP/A
	6	2.0	20.0	2.0	10.0	3.0	10.0	3.0	7.5	3.0	6.0	3.0	5.0	3.0	4.3	SP/A
	7	1.0	10.0	1.0	5.0	1.3	4.3	1.3	3.3	1.3	2.6	1.0	1.7	1.0	1.4	SP/A
	8	1.8	18.0	1.6	8.0	1.8	6.0	1.7	4.3	1.2	2.4	0.7	1.2	0.0	0.0	SG/D
D	1	0.5	5.0	0.5	2.5	0.5	1.7	0.3	0.8	0.0	0.0	−0.5	−0.8	−0.5	−0.7	SP/A
	2	0.8	8.0	1.0	5.0	0.8	2.7	1.0	2.5	1.0	2.0	0.5	0.5	1.0	1.4	SP/A
	3	2.0	20.0	2.0	10.0	2.0	6.7	3.0	7.5	2.0	4.0	3.0	5.0	3.0	4.3	SP/A
	4	0.5	5.0	0.5	2.5	0.5	1.7	0.3	0.8	0.0	0.0	0.5	0.8	0.5	0.7	SP/A
E	1	7.0	70.0	8.0	40.0	7.0	23.3	6.2	15.5	6.4	12.8	4.3	7.2	4.3	6.1	SP/A
	2	1.0	10.0	1.0	5.0	1.0	3.3	2.0	5.0	2.0	4.0	2.0	3.3	3.0	4.3	SP/A
	3	0.2	2.0	0.0	0.0	−0.4	−1.3	−1.0	−2.5	−1.0	−2.0	−1.0	−1.7	−3.0	−4.3	SP/A
F	1	−1.0	−10.0	−1.7	−8.5	−1.5	−5.0	−3.0	−7.5	−3.0	−6.0	−4.0	−6.7	—		SP/A
	2	−1.0	−10.0	−0.5	−2.5	−1.2	−4.0	−3.0	−7.5	−3.0	−6.0	−4.0	−6.7	—		SP/A
	3	0.8	8.0	1.0	5.0	0.0	0.0	−0.7	−1.8	−0.7	−1.4	−2.5	−4.2	−3.0	−4.3	SP/A
	4	−1.5	−15.0	−1.5	−7.5	−0.7	−2.3	−1.0	−2.5	−1.7	−3.4	−0.5	−0.8	−1.0	−1.4	SP/A
	5	−0.2	−2.0	−0.2	−1.0	−0.2	−0.7	−0.2	−0.5	−0.5	−1.0	−1.0	−1.7	−1.2	−1.7	SG/D
G	1	1.0	10.0	1.5	7.5	−1.5	−5.0	−1.0	−2.5	−1.5	−3.0	−2.0	−3.3	−2.0	−2.9	SP/A
	2	−2.0	−20.0	−2.0	−10.0	−2.0	−6.7	−3.0	−7.5	−3.0	−6.0	−3.0	−5.0	−3.3	−4.7	SP/A
	3	2.0	20.0	2.0	10.0	3.0	10.0	2.0	5.0	3.0	6.0	3.0	5.0	3.0	4.3	SP/A
	4	2.0	20.0	2.0	10.0	2.0	6.7	2.0	5.0	2.0	4.0	2.0	3.3	2.0	2.9	SP/A
	5	2.0	20.0	1.0	5.0	2.0	6.7	1.0	2.5	0.0	0.0	1.0	1.7	1.0	1.4	SP/A
	6	2.0	20.0	2.0	10.0	2.0	6.7	2.0	5.0	2.0	4.0	1.0	1.7	1.0	1.4	SP/A

The value indicates difference with the criterion value.
▢ The value indicates the error beyond 2.5 kg for each criterion weight
※The accuracy that the manufacturer shows is ±2 kg or less.
SP/A : Spring system/Analog
SG/D : Strain gauge system/Digital

grip strength is closely related to other muscle strength, physical fitness, and muscle mass. Grip strength is also deemed important for assessment of physical fitness in the elderly, because of its functional role in the performance of activities of daily living[9]. In a related trend for fall prevention, a toe dynamometer has recently been developed to measure toe muscle strength[10,11].

Various factors are being investigated for their influence on grip strength measurements, including measurement posture[9], grip width[12], and number of measurement repetitions[13]. Hand dynamometer validation also warrants consideration. Errors in measurement may result in significant underestimation or overestimation of grip strength. Advance validation before testing and adjustment of hand dynamometers is therefore essential.

The extent of measuring device validation and adjustment for physical fitness tests at many elementary, secondary, and tertiary schools in Japan is not known. The present study may provide some insight into this question. It began with a questionnaire survey of 43 public and private elementary, junior high, and senior high schools concerning their implementation of hand dynamometer validation. The questionnaire responses indicated that 5 (12%) of 43 schools had performed hand dynamometer validation and 38 (88%) had not. Although this survey was small in scale, this finding suggests that many schools in Japan do not perform hand dynamometer validation, for various reasons.

We also performed validation tests for hand dynamometers at schools that had not performed validation, to investigate their accuracy. Only 2 of 30 devices tested were strain-gauge hand dynamometers, and 28 were spring-loaded. Spring-loaded hand dynamometers are generally considered accurate to ±2.0 kg. In contrast, strain-gauge hand dynamometers can generally be adjusted to provide an accuracy of ±0.1 kg, and they are also considered superior to the spring-loaded type because they can be used for 2 to 3 years, depending on frequency of use. The times of purchase ranged from 1976 to 2008, and some of the older dynamometers had last been inspected some 30 years prior to this study.

In the present study, in which an error of ±2.5 kg or more was considered large, the maximum deviation from the reference value was +8.0 kg in a hand dynamometer that showed a mean error of +6.5 kg in the test range of 10-70 kg. Measurements with this dynamometer would thus inherently yield a two-rank overestimation of grip strength on a 10-rank scale.

It was found that, even among the dynamometers at a given school, the measurement errors tended to include both overestimation and underestimation of grip strength. This may be attributable in part to differences in frequency of use among the dynamometers.

In their investigation on the measurement accuracy of six Jamar dynamometers, Harkonen et al.[14] tested each one at five different handle positions with seven weights of 5 kg to 60 kg and found that none of them exhibited any substantial difference in accuracy with differing grip breadths, but noted a tendency for lower accuracy in older dynamometers. In the present study, no relation was found between the period of dynamometer validation and the degree of error, as may be seen in the finding of 3-kg to 5-kg errors in a dynamometer (G-3) last validated 1 year before the present investigation, in contrast to the finding of no large error (except at 70 kg) in two dynamometers (E-2, 3) last validated 5 years before the present investigation. It was concluded that the large errors in the quite recently validated dynamometer (G-3) was probably the result of its high frequency of use. The oldest dynamometer (B-1), which had been purchased 33 years previously, was a case in which no large error was found. Although no relevant records remained, it appears that this dynamometer had been regularly validated.

The proportion of hand dynamometers at each school with an error of ±2.5 kg or more was at least 0% and at most 100%. Overall, the proportion of hand dynamometers found not to be in need of adjustment was 53% (16 hand dynamometers). Results of this study thus indicate that many schools had been performing measurements with hand dynamometers that resulted in large errors. The hand-written reasons given in the questionnaires for non-implementation of hand dynamometer validation included such problems as 1) insufficient budget allocations; 2) forgetfulness in the midst of busy schedules, despite an understanding of the need for validation; and 3) lack of knowledge concerning the method of validation, despite an awareness of the need for it.

It should be noted that with some of the dynamometers, the error (deviation from the reference value) was fairly uniform throughout the grip-strength test range of 10-70 kg, and with others the error varied throughout the test range. If the error is uniform throughout this range and the deviation is displayed by the hand dynamometer, then in actual use it is possible to compensate for the error in succeeding measurements. For dynamometers showing non-uniform errors throughout the test range, it is possible to reduce the error size by constructing and applying a compensation formula with X as the measured value and Y as the estimated actual value. Such expediencies, however, are not really desirable, and it is preferable either to have a specialized agency adjust any hand dynamometer that yields large errors or to replace it with a new one.

It may be possible for the local board of education or a local school serving as a representative to set up a dynamometer validation post with a device such as the spring-type and strain gauge used in the present study to facilitate periodic validation, and where necessary, adjustment (or compensation formula derivation) for each school with its own hand dynamometers. Moreover, for cases in which the error is found to be too large, it would be advisable to consider either contracting a specialized agency to implement the hand dynamometer correction or purchasing a new one.

Obligatory record-keeping of the times of dynamometer maintenance and new dynamometer purchase may also be useful for future maintenance scheduling. The present study did not provide information useful for appropriate maintenance scheduling, and further study will be necessary to determine the relation of error occurrence and degree to the time of purchase, time of previous validation, and number of individuals measured per year.

In addition to the heightened understanding of the importance of hand dynamometer validation, one favorable result of the present study has been the decision by some schools to dispose of old instruments showing large errors and replace them with new ones.

Schools in Japan are currently confronted with major problems with budget cutbacks on educational expenditures. The investigation in this study only included a few schools, but there may be many schools that do not carry out the validation testing of hand dynamometers, which can be inferred from comments on the questionnaire. The present study has raised an important issue relating to the practice of health and fitness education. In the on-site measurement of children's health and physical fitness at schools, proper management and assurance of the accuracy of the measurement devices is unquestionably important. The present study has highlighted the issues associated with hand dynamometers used in physical fitness tests, but this is only one small part of the overall problem. Going forward, it will be necessary to discuss means of further heightening the awareness of teachers in related positions of specialization while discussing methods for effective explanation of the need to secure budgetary allocations that will meet educational costs.

References

1. Ministry of Education, Culture, Sports, Science & Technology, 'Report & Statistics. Physical fitness and motor ability investigation. statistical abstract 2009 edition' (2011). http://www.mext.go.jp/b_menu/toukei/chousa04/tairyoku/1261241.htm (http://www.mext.go.jp/component/b_menu/other/__icsFiles/afieldfile/2010/10/12/1298223_7.pdf)
2. Hara M, Saitoh E, Itoh S, Mutoh Y (2003) Physical activity and childhood obesity. J Phys Educ Med 4: 81-89 [*In Japanese with English Abstract*]
3. Nakata Y, Sasai H, Okura T, Tanaka K (2008) Effects of exercise training without energy restriction on metabolic syndrome and its component factors in obese men. Bull Inst Health and Sport Sci Univ of Tsukuba 31: 203-207 [*In Japanese with English Abstract*]
4. Yorozu M, Kinami C, Mikuni K, Yamamoto M

(2006) Trend of research prevention of childhood obesity and lifestyle in Japan. J Nurs Social Services 13: 51-58

5. Watanabe K, Nakadomo F, Okada M, Okuda T, Ogawa N, Maeda K (1993) Influences of body composition and habitual exercise on physical fitness and motor ability in the growing aged. J Educ Health Sci 39 (2) : 205-213 [*In Japanese with English Abstract*]
6. Watanabe K, Watanabe H, Ogawa Y, Yoshida Y, Takahashi S, Wadazumi T, Imaki M (2005) Relationship of extremity muscle mass to muscular strength system function and cardiopulmonary function in young men. Health Behav Sci 4 (1) : 1-9
7. Laboratory of physical education Tokyo Metropolitan University (1989) Ⅱ Grip strength. In: Laboratory of physical education Tokyo Metropolitan University (eds) Physical fitness standards of Japanese people, Fumaido, Tokyo, pp.98-101 [*In Japanese*]
8. Yazawa A, Watanabe K, Saruwatari A, Imaki M (2006) Relationship between extremity muscle mass and physical fitness in obese middle-aged and elderly women. Jpn J Health Fit Nutr 11 (2) : 3-9
9. Otsuka T, Domen K, Liu M, Sonoda S, Saitoh E, Tsubahara A, Kimura A, Chino N (1994) Grip strength of healthy elderly individuals—Method of measurement and strength—. Jpn J Rehabil Med 31: 731-735 [*In Japanese with English Abstract*]
10. Fukumoto T, Uritani D, Maeoka H, Okada Y, Matsumoto D (2011) Development of a toe grip dynamometer. Bulletin of Kio University 13: 31-35 [*In Japanese with English Abstract*]
11. Kito N, Ihara H, Shimazawa S, Baba Y, Taguchi N (2001) Effects of toe motion exercise to prevent falls in the elderly. J P T A 28 (7) : 313-319 [*In Japanese with English Abstract*]
12. Yoshida K, Yoshifuku Y, Adachi Y, Aoki T (1997) An Examination into the dependence of the grip strength measured with a popular type (smedley type) dynamometer on the grip width and experience, and its circadian change. J Mind-Body Science 6 (1) : 17-25 [*In Japanese with English Abstract*]
13. Maki M, Daiguji T (1993) A study on the appropriate method of grip strength measurement. HUSCAP 6 : 71-76 [*In Japanese with English Abstract*]
14. Harkonen R, Harju R, Alaranta H (1993) Accuracy of the Jamar dynamometer. J Hand Ther 6 (4) : 259-262