ORIGINAL RESEARCH

Determining a Minimum Wrestling Weight for Interscholastic Wrestlers

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BACKGROUND. Junior high school and high school boys participating in interscholastic wrestling are at risk when allowed to compete in a weight class that is too low, which can adversely affect their growth and general health. This study compared 3 different methods that physicians may use to determine the minimum wrestling weight of junior high and high school wrestlers.

METHODS. At an unannounced school visit, the minimum wrestling weight of the wrestlers was calculated on the basis of 3 different methods of estimating the percentage of body fat: (1) Lange calipers; (2) the Ross Laboratories Adipometer calipers; and (3) bioimpedance analysis.

RESULTS. Over a 2-year period, 104 boys interested in interscholastic wrestling participated in this comparison. Correlation among all 3 methods was very high (consistently more than 98%). However, the 2 caliper methods agreed most closely with each other, with the Ross caliper overestimating minimum wrestling weight by an average of 0.6 kg. As compared with the Lange caliper method, bioimpedance underestimated minimum wrestling weight by an average of 2 kg.

CONCLUSIONS. The agreement between the 2 caliper methods was sufficient to allow the simple, inexpensive caliper to be used instead of the more expensive Lange caliper. The bioimpedance method, which overestimated the percentage of body fat compared with the other methods, would allow too much weight loss. Using 3 quick skinfold measurements obtained with the inexpensive plastic Ross calipers and a chart of values, physicians can accurately calculate minimum wrestling weight for interscholastic wrestlers.

KEY WORDS. Adipose tissue; anthropometry; body weight; electric impedance; wrestling. *(J Fam Pract 1999; 48:208-212)*

Family physicians frequently perform preparticipation physical examinations for students who want to participate in interscholastic sports in junior high and high school. Physicals for wrestlers present a unique challenge, since the physician is required to certify a minimum weight class at which the student can compete. In this age group, body fat as a percentage of total weight should not be less than 5% to7%.[1,2] Often there is pressure on physicians to set the minimum wrestling weight (MWW) as low as possible, which can lead to practices to induce rapid weight loss (weight cutting). Methods of weight loss, including vigorous exercise, fluid restriction, hot environments, and the use of diuretics, emetics, and laxatives, can lead to adverse effects on cardiovascular function, electrical activity, renal function, electrolyte balance, and muscular endurance and strength.[3-45] Three cases of dehydration- and hyperthermia-related deaths have recently been reported involving collegiate wrestlers who were trying to "make weight."[6] The wrestling weight in the 3 wrestlers was set from 25 to 37 pounds below their preseason weight, or a loss of approximately 15% of their total body weight.

Many methods are available for calculating MWW. At one end of the spectrum is the intuitive approach, in which the MWW is estimated on the basis of the current weight of the wrestler, his desired weight classification, and the physician's experience with estimating body composition. At the other end of the spectrum are several methods of body fat analysis, which estimate the percentage of body fat of the wrestler from which the MWW can be calculated. Standard weight tables developed by insurance companies are not appropriate for athletes of this age for setting the MWW, since they are based on national averages for weight and height.

Body fat estimation can be performed using hydrostatic (underwater) weighing, bioelectrical impedance analysis, skinfold measurements, or measurements of skeletal dimensions such as height, chest diameter and depth, and wrist diameter. There is no consistently accepted gold standard for determining the percentage of body fat and MMW. Hydrostatic weighing is often considered the most accurate clinically available method, although Lange calipers produce similar estimates.[7] This study compared the accuracy of 2 skinfold measuring devices and a bioimpedance method to determine the minimum wrestling weight of junior high and high school wrestlers.

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METHODS

Two methods used skinfold measurements with different skinfold calipers, and a third method measured bioelectrical impedance (bioimpedance) to calculate the percentage of body fat.

All boys interested in interscholastic wrestling at either the junior high or high school level in one school district were included in the study. To avoid purposeful alterations in hydration status, all measurements were performed at a single, unannounced visit to the school during school hours. The study was performed over a 2-year period.

Following determination of height and weight, the 3 methods of estimating body fat were performed on each wrestler by a single, separate investigator experienced in the technique. An investigator was assigned to each method and was unaware of the results of the other methods. All sets of tests were performed in the same order.

Anthropometric measures were obtained using 2 different calipers (Figure 1). The Lange caliper is a large metal caliper most frequently used by researchers and dietitians to estimate body fat. The Adipometer is a small plastic caliper distributed at no charge by Ross Nutritional products and was used to obtain a second set of measurements.

Skinfold measurements were obtained according to the usual method. Measurements were taken on the right side of the body at the biceps, triceps, subscapular, suprailiac, and abdominal areas, though only triceps, subscapular, and abdominal measurements were used in calculations. All measurements were performed twice and repeated if they varied by more than 0.5 mm. Lange caliper skinfolds

FIGURE 1

Lange skinfold caliper (left) and Adipometer skinfold caliper

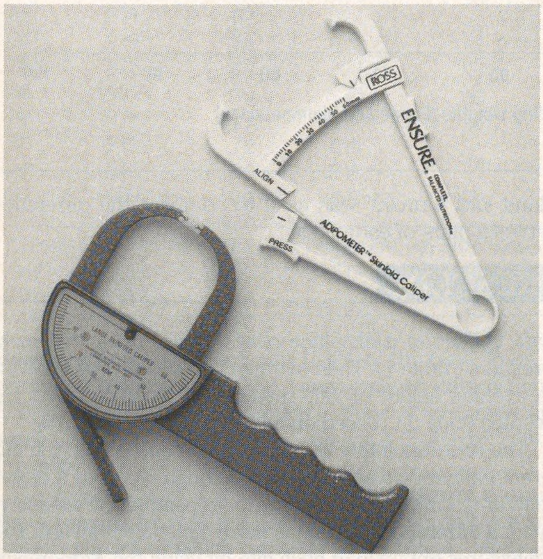


TABLE 1

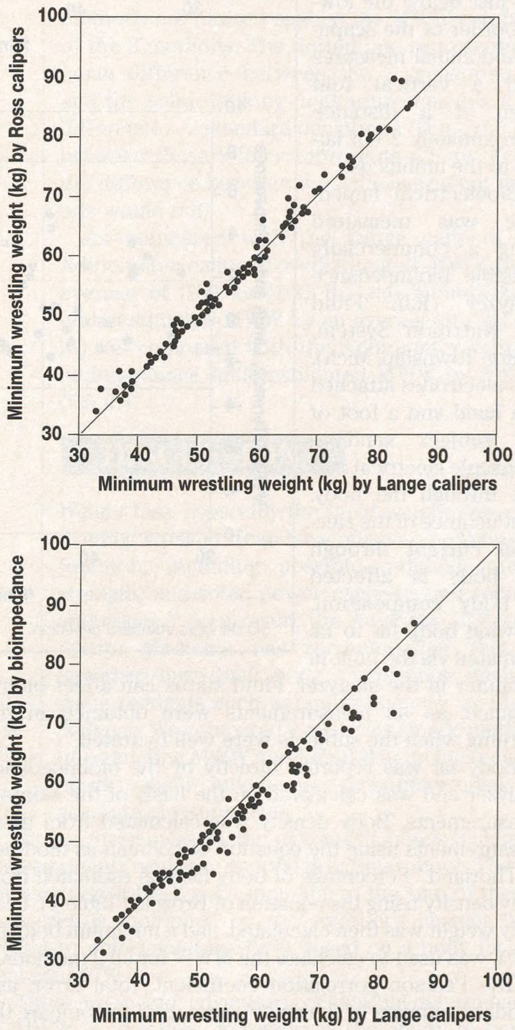
Characteristics of the Wrestlers Who Had Their Body Fat Percentage Tested (N = 104)

Characteristic	Mean	SD	Range
Age, years	14.9	1.55	12.0 - 18.0
Body weight, kg	61.4	14.93	35.5 - 110.9
Height, cm	165.5	9.93	138.4 - 189.2
Body fat, %*	12.8	5.1	6.4 - 32.5
Minimum weight, %†	56.8	12.6	33.6 - 86.2

SD denotes standard deviation.
* Using the conversion from body density to body fat percentage by Brozek.[9]
†Calculated as fat-free body weight/0.93.

FIGURE 2

The degree of agreement between methods.



were measured by a sports science professional, and Adipometer caliper skinfolds were measured by a family physician.

Skinfold measurements were obtained in the following manner. For the triceps measurement, a vertical fold was measured on the posterior midline, halfway between the acromion and olecranon processes. The subscapular measurement was obtained using a diagonal fold just below the lowest border of the scapula. Abdominal measures used a vertical fold taken at a distance approximately 2 cm lateral to the umbilicus.

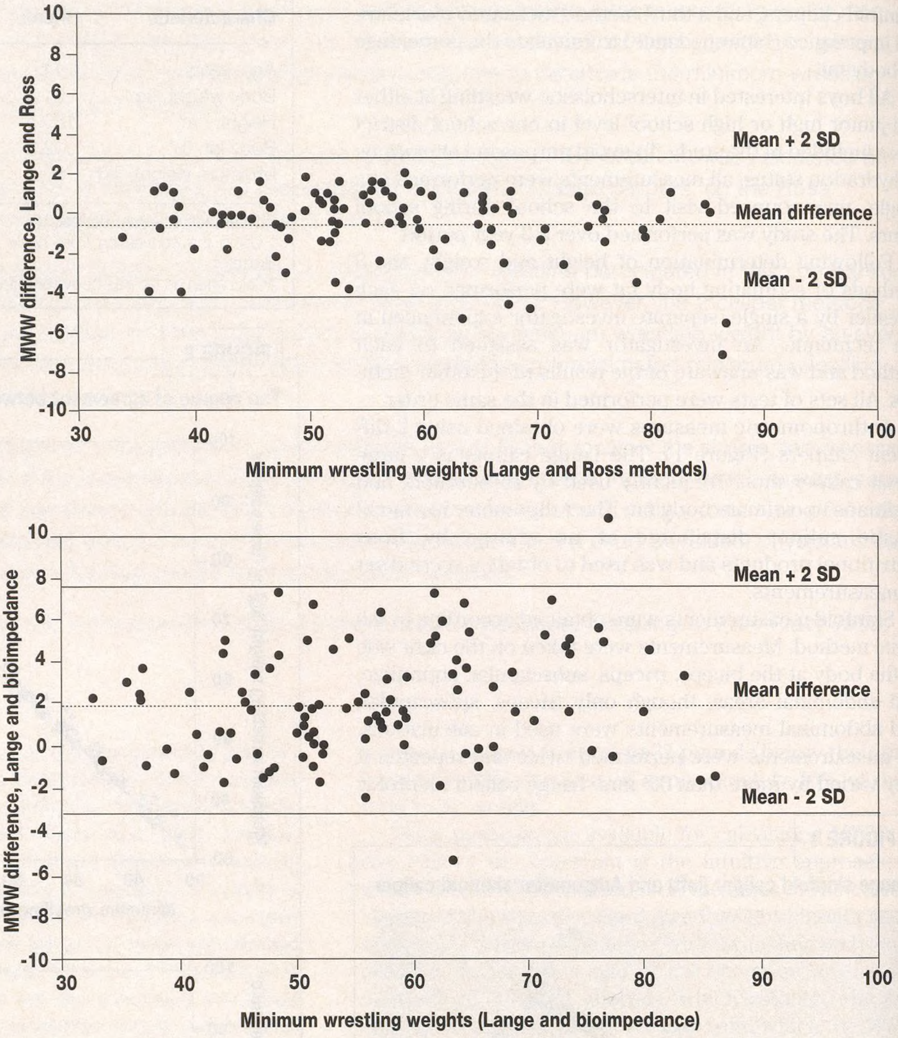
Bioelectrical impedance was measured using a commercially available bioimpedance analyzer (RJL Fluid and Nutrition System, Clinton Township, Mich). Two electrodes attached to a hand and a foot of the subject send a minuscule electrical current through the body. Conductance of the electrical current through the body is affected by body composition, allowing body fat to be estimated via the built-in computer in the analyzer. Fluid status can affect bioimpedance, so all measurements were obtained in the morning when the subjects were well hydrated.

Body fat was reported directly by the bioimpedance analyzer and was calculated on the basis of the skinfold measurements. Body density was calculated from these measurements using the equation of Lohman as modified by Thorland.[8] Percentage of body fat was estimated from body density using the equation of Brozek[9] (Table 1). Lean body weight was then calculated, and a minimum body fat of 7% was used to calculate the MWW for all 3 methods.

The Pearson correlation coefficient, total error, and standard estimate of the error[10] were used to compare the 3 methods. In addition, the degree of agreement method of Bland and Altman[11] was used to compare the difference between pairs of estimates.

FIGURE 3

The differences in estimates of minimum wrestling weights, by method.



SD denotes standard deviation.

RESULTS

Data collection took place over 2 years using 104 male wrestlers (Table 1). Their average age was 14.9 years, with an average height of 1.65 meters and weight of 61.2 kg. Average body fat (based on all 3 methods) was 12.7%.

The reproducibility of measures obtained with the different calipers was compared. Although we used a difference of 0.5 mm as a cut-point for repeating the measurement, a difference of 1 mm is more clinically relevant. The 2 measures obtained at each site by using the Adipometer

TABLE 2

Calculation of Minimum Wrestling Weight*

This Table can be used to calculate minimum wrestling weight of junior high and high school students, using skinfold measurements.

To use: Obtain skinfold measurements, in millimeters, of the triceps, subscapular, and abdominal areas. Add all 3 together, and find the corresponding factor on the table below. Multiply the wrestler's actual body weight by this factor to determine the minimum wrestling weight.

Skinfolds mm	Factor	Skinfolds mm	Factor	Skinfolds mm	Factor
11	1.009	43	.905	75	.804
12	1.006	44	.902	76	.801
13	1.003	45	.899	77	.798
14	.999	46	.896	78	.795
15	.996	47	.893	79	.792
16	.993	48	.889	80	.789
17	.990	49	.886	81	.786
18	.986	50	.883	82	.782
19	.983	51	.880	83	.779
20	.980	52	.877	84	.776
21	.977	53	.873	85	.773
22	.973	54	.870	86	.770
23	.970	55	.867	87	.767
24	.967	56	.864	88	.764
25	.964	57	.861	89	.761
26	.960	58	.858	90	.758
27	.957	59	.854	91	.755
28	.954	60	.851	92	.752
29	.951	61	.848	93	.749
30	.947	62	.845	94	.746
31	.944	63	.842	95	.743
32	.941	64	.839	96	.740
33	.938	65	.835	97	.737
34	.934	66	.832	98	.734
35	.931	67	.829	99	.731
36	.928	68	.826		
37	.925	69	.823		
38	.921	70	.820		
39	.918	71	.817		
40	.915	72	.814		
41	.912	73	.810		
42	.909	74	.807		

* Based on a body fat of 7%. Body density was calculated using the equation of Lohman, as modified by Thorland.[8] Percentage of body fat was calculated using the equation of Brozek.[9]

disagreed by more than 1 mm 15.4% of the time. Pairs of measures obtained with the Lange caliper differed only 3.3% of the time. The difference in rates of intra-rater disagreement was statistically significant (chi-square = 46.8, $P < .0001$).

Correlation was very high among all 3 pairs of comparisons, ranging from 97.9% between the bioimpedance and Lange calipers to 99.2% between the 2 caliper methods. The total error and standard estimate of the error (SEE) was 1.71 kg (SEE = 0.498) between the 2 caliper methods, 2.46 kg (SEE = 1.166) between the Lange calipers and bioimpedance, and 2.35 kg (SEE 1.125) between the Ross calipers and bioimpedance.

The degree of agreement is illustrated in Figures 2 and 3. In Figure 2, the 3 measurements are compared directly with one another. Perfect agreement would align all points on the 45-degree "line of equality" shown on the graph. Using the Lange caliper estimations as the standard, we found close agreement of the Adipometer caliper estimations, with wider and consistent variation using bioimpedance. Calculation using the Ross caliper measurements slightly overestimated the MWW, whereas bioimpedance consistently set the MWW lower than the Lange caliper estimation.

In Figure 3, the differences in MWW among the methods are plotted against the MWW estimates of the 3 methods. The dotted line represents the mean difference between the 2 measurements and the solid flanking lines represent this mean difference + 2 standard deviations. Thus, the area between these 2 lines represents where 95% of the difference between the 2 measurement methods would fall.

As compared with the Lange calipers, the Adipometer calipers overestimated MWW by an average of 0.59 kg (1.31 lb) and bioimpedance underestimated MWW by an average of 2 kg (4.4 lb). As compared with the Adipometer calipers, bioimpedance underestimated MWW by 2.49 kg (5.5 lb).

DISCUSSION

Weight loss, especially the rapid weight loss practiced by wrestlers, can have effects on physiologic function, including possible reduced muscle strength, anaerobic power capacity, and reduced endurance.[2-5] As a result, the American College of Sports Medicine has recommended that all wrestlers have their body composition analyzed using methods such as anthropometry or bioimpedance. We compared 3 relatively simple methods of estimating MWW and found that an inexpensive plastic caliper could be used to produce quick and accurate measurements.

To use these calipers, the examiner obtains 3 skinfold measurements using the method described above. The factor listed on Table 2 corresponding to the sum of these 3 measures is multiplied by the wrestler's current body weight to determine his MWW based on a body fat percentage of 7%.

There are several advantages of skinfold determination of MWW in wrestlers. Foremost is the ability to conveniently perform the estimation in an examination room or at a high school. A second advantage is the low cost, compared with other methods. Though Lange calipers are expensive (approximately $200), the Adipometer plastic calipers that we used were supplied by Ross Nutritional Products at no cost.

Bioimpedance analyzer systems are less useful than skinfold measurement techniques. The systems are expensive ($4,500) and, as shown in this study, tend to overestimate the percentage of body fat in lean individuals.[12,13] Using this method would result in an MWW that possibly would allow wrestlers to lose more weight than is safe.

This study is limited in several ways. Hydrostatic weighing was not used as the standard against which these 3 methods of estimation would be compared. However, previous studies have shown that a skinfold measurement using Lange calipers and the modified Lohman equation produces clinically equivalent estimations of MWW,[7,12] even in this age group.[13]

To ensure blinding, 2 different investigators in separate rooms obtained measurements using the 2 different calipers. One investigator obtained all the measurements with the Adipometer, and a second investigator used the Lange calipers for all readings. In this way there was no chance that readings using one caliper could be influenced by the measurements using the other caliper. It is possible that one investigator could be more skilled in the use of calipers, thus introducing a systematic bias into the results.

Skinfold measurements using the Adipometer calipers were performed by a family physician who frequently performed wrestling preparticipation physicals and who was familiar with skinfold measurement techniques. Although the technique is simple and reproducible,[14,15] it is unclear whether untrained physicians will be able to produce reliable results. In addition, there is the concern that continuous use of the caliper could lead to material fatigue and alter the results. We do not have any data on the useful life of the calipers.

The difference in rates of intra-rater disagreement was statistically significant (15.4 % for Adipometer measures and 3.3% for Lange calipers, $P < .0001$). This difference is likely due to the instability of the plastic, and users of these calipers should repeat all measurements and perform additional skinfold measures if the repeated values are not similar.

We used the modified Lohman[8] equation to calculate body density and the method of Brozek[9] to calculate percentage of body fat. Other equations using these or additional skinfold measurements have been proposed, though comparative studies with hydrostatic weighing have found the methods of Lohman and Brozek to have the best predictive ability.[13]

One disadvantage of using skinfold measurements, in addition to the availability of the calipers, is that the calculations required to interpret the skinfolds are tedious. We have removed this impediment by simplifying an accurate equation to a table of factors. After obtaining the skinfold measures, the numbers can be summed and the corresponding factor is located on a chart (Table 2). Multiplying the wrestler's body weight by this factor yields the MWW based on a 7% body fat composition.

CONCLUSIONS

An inexpensive caliper can be used to accurately obtain skinfold measurements. Using the table of values, these skinfold measures can be used to quickly convert to an MMW for adolescent wrestlers.

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REFERENCES

1. Wroble RR. Hoegh JT, Albright JP. Wrestling. In: Reider B, ed. Sports medicine. The school-age athlete. Philadelphia, PA: WB Saunders Co, 1991:549.
2. American College of Sports Medicine. Position stand: weight loss in wrestlers. Med Sci Sports Exerc 1996; 28:ix-xii.
3. Horswill CA. Applied physiology of amateur wrestling. Sports Med 1992; 14:114-43.
4. Steen SN, Brownell KD. Patterns of weight loss and regain in wrestlers: has the tradition changed? Med Sci Sports Exerc 1990; 22:762-8.
5. Sawka MN, Young AJ, Francesconi RP, Muza SR, Pandolf KB. Thermoregulatory and blood responses during exercise at graded hypohydration levels. J Appl Physiol 1985; 59:1394-401.
6. Hyperthermia and dehydration-related deaths associated with intentional rapid weight loss in three collegiate wrestlers — North Carolina, Wisconsin, and Michigan. November-December 1997. MMWR 1998; 47:105-8.
7. Oppliger RA, Looney MA, Tipton CM. Reliability of hydrostatic weighing and skinfold measurements of body composition using a generalizability study. Hum Biol 1987; 59:77-96.
8. Thorland WG, Tipton CM, Lohman, et al. Midwest wrestling study: prediction of minimal weight for high school wrestlers. Med Sci Sports Exerc 1991; 23:1102-10.
9. Brozek J, Grande F, Anderson T, Keys A. Densitometric analysis of body composition: revision of some quantitative assumptions. Ann NY Acad Sci 1963; 110:113-40.
10. Lohman TG. Skinfolds and body density and their relation to body fatness: a review. Hum Biol 1981; 53:181-225.
11. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1:307-10.
12. Oppliger RA, Nielson DH, Vance CG. Wrestlers' minimal weight: anthropometry, bioimpedance, and hydrostatic weighing compared. Med Sci Sports Med 1991; 23:247-53.
13. Clark, RR, Kuta JM, Sullivan JC, Bedford WM, Penner JD, Studesville EA. A comparison of methods to predict minimal weight in high school wrestlers. Med Sci Sports Med 1993; 25:151-8.
14. Ryan AS. The accuracy of the Ross Laboratories Adipometer skinfold caliper. Clin Pediatr 1985; 24:174-5.
15. Jung E, Kaufman JJM, Narins DC, et al. Skinfold measurements in children. Clin Pediatr 1984; 23:25-8.