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Development and initial assessment of objective fatigue measures for apple harvest work

Giulia Earle-Richardson[a,*], Paul L. Jenkins[b], David Strogatz[c], Erin M. Bell[c], John J. May[a]

[a]New York Center for Agricultural Medicine and Health, Bassett Healthcare, 1 Atwell Rd., Cooperstown, NY 13326, USA
[b]Bassett Research Institute, Cooperstown, NY, USA
[c]University at Albany, School of Public Health, Rensselaer, NY, USA

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Abstract

Previous research has shown that neck, back and shoulder musculoskeletal strain is a major occupational health problem affecting migrant orchard harvest workers. Researchers seek to measure the effect of an ergonomic modification to the apple picking bucket on muscle fatigue, however objective measures for use in the orchard are not yet available.

The purpose of this study is to develop simple back, shoulder or arm strength measures, which detect statistically significant drops in strength over one workday. Candidate muscle strength measures were piloted in the laboratory, adapted for the orchard and evaluated ($n = 102$). Data were analyzed for morning to afternoon fatigue, and for correlation between fatigue score and hours worked.

In the laboratory, the timed arm hold (35.7% time reduction, 95% CI: 21.81–49.61), and the timed spinal extension (31.8% time reduction, 95% CI: 23.54–39.96) showed significant fatigue. In the orchard ($n = 102$), only the timed arm hold showed significant (11.4%, $p < .0001$) fatigue. The potential effect of field conditions and subject motivation on these results needs further exploration.

Keywords: Ergonomics; Musculoskeletal strain; Migrant farmworkers

1. Introduction

Migrant and seasonal farmworkers provide much of the manual labor used in agriculture for planting, pruning and harvesting of fruits and vegetables in the US. One common result of these activities is musculoskeletal strain due to stooping (ground crops), reaching (orchard fruit), and carrying of heavy loads. There is some research evidence to suggest that extreme powerlessness among this largely foreign-born, uneducated and sometimes undocumented workforce contributes to injury frequency (Salazar et al., 2005).

1.1. Epidemiology of back, neck and shoulder strain among apple harvest workers

A number of published studies place musculoskeletal strains among the most frequent injuries for migrant and seasonal farmworkers (Northeast Center for Agricultural and Occupational Health, 2003, unpublished; Villarejo and Baron, 1999; Osorio et al., 1998; Husting et al., 1997; Ciesielski et al., 1991). One study reported an overall strain/sprain prevalence of 31% per season (McCurdy et al., 2003).

Frequent occurrences of muscle pain (a common symptom of strain) have also been found in orchard work. For example, a study in Japan examining musculoskeletal symptoms in apple and pear work found self-reported neck pain and stiffness ranging from 25–50% of workers in apples and from 40–60% of workers in pears. Sixty-five to 70% of workers in both crops reported stiffness in the shoulder, with roughly a third of apple workers and half of pear workers reporting shoulder muscle pain. Similar rates of neck pain with motion were reported as well (Sakakibara et al., 1995). Calisto (1999) also found an elevated prevalence of pain among fruit growers in the upper and lower back (19% and 57%, respectively), and in the neck and shoulders (both at 38%).

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*Corresponding author. Tel.: +1 607 547 6023; fax: +1 607 547 6087.
E-mail address: gearlerichardson@nycamh.com
(G. Earle-Richardson).

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In addition to strain and pain outcomes, long periods of exposure to the ergonomic hazards of awkward posture and weight bearing among orchard workers have been documented (Earle-Richardson et al., 2004; Calisto, 1999). As a proportion of the workday, these periods of exposure are as long, or longer than those found in construction and nursing, two reportedly high-risk occupations (Earle-Richardson et al., 2004).

1.2. Prevention of strain through ergonomic intervention

The New York Center for Agricultural Medicine and Health has developed an ergonomic bucket modification to reduce the load borne by the back, neck and shoulders of apple harvest workers, consisting of a supporting hip belt which redistributes weight from the upper back, neck and shoulders to the lower trunk, a preferable vertical height for weightbearing, and also maintains the load close to the body (Waters et al., 1994; Pheasant, 1991; Page, 1985). The intervention (shown in Fig. 1), is more fully described in a previous issue of this journal (Earle-Richardson et al., 2005), and in a preliminary laboratory EMG study (Earle-Richardson et al., 2006).

1.3. Evaluating the hip belt intervention in the orchard

As with the laboratory research, it was necessary to use an intermediate endpoint in the development of musculoskeletal strain because there currently exists no objective physical measure of the outcome. However, because it was not feasible to conduct EMG research in the orchard, the development of mechanical methods that could be used in the orchard environment was undertaken.

Fig. 1. An apple harvest worker climbs a ladder to pick apples using the intervention belt attached to his regular picking bucket.

Detection of muscle fatigue through measurement of changes in morning to afternoon maximum voluntary contraction was selected as an endpoint. According to a model proposed by Armstrong et al. (1993), the development of musculoskeletal strain can be thought of as a sequence of four events: *exposure*, *internal dose*, *capacity* and *response*. In this context, *internal dose* is the body's initial response to a given load. One example of internal dose is muscle fatigue. While other capacity factors, such as rest time and overall condition, may ultimately determine whether an individual with a given internal dose develops muscle strain, an intervention that significantly reduces the internal dose can reasonably be called beneficial in preventing or reducing muscle strain. A number of other studies describe a similar process (Clarkson and Hubal, 2002; Proske and Morgan, 2001; Clarkson and Sayers, 1999; Sjogaard and Sogaard, 1998; Green, 1997; Clarkson and Newham, 1995; Brystrom and Fransson-Hall, 1994; Hagberg, 1981).

1.4. Muscle strength measures

In the context of this study, fatigue is defined as the pre- to post-exposure decline in maximum performance occurring after a period of exertion (Lanza, 1999). Published fatigue studies of this type measure either time holding a posture, one-time attainment of a maximum reading on a dynamometer or possibly a dichotomous pass/fail metric for performance of weighted or non-weighted tasks (Lee et al., 2001; Nussbaum et al., 2001; Hughes et al., 1999; Vollestad, 1997; Bloswick and Mecham, 1994).

1.5. Initial steps in muscle fatigue measurement instrument development

Before being used in a large orchard trial, the sensitivity of each type of performance measure for apple harvest work needed to be evaluated. For the purposes of the current study, a measure deemed effective was one that detected a change in muscle strength occurring over an orchard harvest workday. This methodology is unique in that other published studies take pre- and post-measurements over a relatively short interval of time (no more than 2 h), whereas this method seeks to measure a real work day of actual farm workers (6–8 h). Interventions can thus be evaluated on their ability to reduce one-day muscle fatigue.

2. Methods

2.1. Study design and hypotheses

2.1.1. Design

The study has two phases: a laboratory phase and an orchard phase. Both phases are experimental in design.

Beginning first in the laboratory with volunteers, pre- to post-work muscle strength measures are used to identify extent of muscle fatigue. Successful tests were then subjected to the same study process, using actual farm-workers in the orchard. Table 1 shows the details of the laboratory and orchard evaluation phases.

2.1.2. *Hypotheses*

Laboratory phase hypothesis: one or more musculoskeletal strength (or endurance) measure can be identified that shows a statistically significant fatigue effect of 10% or more among laboratory volunteers after 2 h of simulated apple picking.

Orchard phase hypothesis: one or more musculoskeletal strength (or endurance) measure can be identified that shows a statistically significant fatigue effect of 10% or more among seasonal apple harvest workers after 8 h of apple harvest work.

2.2. *Data collection*

For both the laboratory and orchard testing, an instructor and a recorder worked at each testing station. The instructor explained the measures to the subject and adjusted the test equipment to the subject's physical dimensions. The recorder assisted in the adjustment process and recorded all data relevant to the test. This included recording the settings for the subject's physical dimensions so that these settings could be duplicated in the afternoon test session.

2.2.1. *Laboratory testing*

This phase was conducted on eight research staff personnel using 2 h of simulated picking conditions and three muscle measures. One day of testing was performed on each subject in this phase.

The first measure, the timed spinal extension, involved timing subjects for how long they could hold a maximum spinal extension lift while lying face down on an examining table. The second measure, the scapular elevation was comprised of three parts: one for both shoulders, and one each for the left and right shoulders. The third measure, the timed arm hold, was also performed separately for both left and right arms.

Each of these measures was administered both before and after 2 h of simulated apple picking, which involved having the subject climb a stepladder and fill a standard apple bucket with apples arranged at various heights on a series of shelves. The subject then descended the ladder and released the apples out of the bottom of the bucket (through a reclosable opening) into a bin. This process continued for 2 h, after which the post-test was administered.

Peak and mean exertion levels were recorded for maximum exertion measures after each of three repetitions using a dynamometer. Seconds to failure was used as the endpoint for timed endurance measures (timed spinal extension and timed arm hold). Rest periods of 15 s were given between maximum contraction measures using the dynamometer, and 1 min between timed maximum endurance measures (Figs. 2,3).

2.2.2. *Orchard testing*

Two of the three laboratory measures were further tested in the orchard. The scapular elevation measure was dropped from further consideration based on laboratory results. The timed arm-hold measure was performed for the dominant arm only. For the spinal extension an upright

Table 1
Summary of candidate muscle test trial data used in the current analysis

	n	Measures evaluated*	Hypotheses tested	Statistical analyses
A. Laboratory testing (2 h simulated picking)	8	standing scapular elev. mean—left	"Fatigue score > 0" with 2 h simulated picking	Wilcoxon ranks sum
		standing scapular elev. peak—left standing scapular elev. mean—right standing scapular elev. peak—right 2-shoulder mean 2-shoulder peak timed arm hold-right timed arm hold-left timed spinal extension		
B. Orchard testing	102	timed arm hold	"Fatigue = 0" and "Fatigue not correlated with hours worked"	Wilcoxon ranks sum Pearson correlation Spearman correlations
		standing spinal extension mean standing spinal extension peak		

*"Mean" and "peak" designations are variations of dynamometer-based tests, the former taking the mean value over a 5-s contraction, and the latter the peak reading over a 5-s contraction.

Fig. 2. Administration of the timed arm hold in the orchard.

Fig. 3. Administration of the standing spinal extension in the orchard.

stand was constructed that allowed the subject to perform standing up. Three repetitions of each measure were performed, with peak and mean exertion values recorded. A 15 s break was provided between each spinal extension repetition, and 1 min between each arm-hold repetition.

An additional procedural modification involved the institution of a "warm-up" period. This involved delaying the baseline observations until the subject had completed a minimum of 30 min of picking. These steps were taken on the advice of the study's physical therapist in order to reduce the effect that a lack of muscle warm-up might have on the morning versus afternoon comparison. Similarly, all post-testing was completed at the end of the picking day, but prior to the actual cessation of work, in order to assure that the subject did not have a muscle recovery period prior to the administration of the afternoon test.

A total of 27 apple harvesters were measured. Subjects were tested in two groups ($n = 7$; $n = 20$). Two testing stations were set up and 10 subjects were tested at each station. Thus, with two test stations, it was possible to test the 20 subjects in approximately 2 h and 30 min. This meant that the last subjects tested had been picking apples for approximately 135 min before their morning test.

Because of this significant time lag, the order of testing for the subjects was kept the same for the morning and afternoon sessions. This assured that the interval between tests was roughly the same for each subject. To do this, an additional researcher, termed the runner, would go into the section of orchard being harvested and return to the testing site with two workers. This process was repeated until all workers had been cycled through the test session.

2.2.2.1. Timed arm hold measure—administration. This measure made use of the dynamometer stand (see Appendix) to house a vertical pole, and to provide body stabilization during the timed measure. Other equipment included a hand-held dumbbell (4.54 kg for men, 2.27 kg for women) weight, a stopwatch and an adjustable pole with contact light designed to stay lit as long as the hand was in contact with the bar.

The subject stood on the platform of the dynamometer stand, facing the vertical post, leaning gently against the braces. To perform the test, the subject was instructed to hold the weight in the dominant hand, raise it up and hold it up against the contact pole as long as possible. A timer began when the subject made contact with the bar, and continued until the arm dropped away from the top of the pole arm and the light was no longer lit. Then the subject rested for 1 min, and repeated the test and rest cycle two more times.

2.2.2.2. Standing spinal extension measure—administration. This test employed a Chatillon CSD 300 strength dynamometer (see Appendix). This portable dynamometer measures pulling force in pounds over a 5-s interval. It provides readings on the mean and peak pulling force for the interval, storing up to five 5-s intervals and provides a coefficient of variation for all the tests stored in memory. The dynamometer was housed in a stand, which has a brace on which the subject rests the upper back. This brace is also connected to the dynamometer and stabilized by the stand itself. It also has two other adjustable braces, one just below the knee and one at hip height.

The subject was asked to stand on the platform facing the vertical post, with legs and hips just touching the leg and hip braces. The brace was vertically adjusted so that the dynamometer was on the same horizontal line as the subject's sternum, and horizontally adjusted so that when the subject was standing erect, the chain connecting the brace to the dynamometer had no slack. The hip brace was vertically adjusted to the hips, and the leg brace 1 inch above the knee. All adjustments were scaled so that the precise location for a given subject could be recorded and replicated for the afternoon test.

The subject performed the measure by pulling with the upper back as hard as possible (pressing the thighs and hips forward into the stand) until told to stop. After a 15-s rest, the measure was repeated two more times. After three repetitions, mean values and then the peak values for each interval were manually recorded from the dynamometer.

These two measures were administered in an identical manner in the laboratory and the orchard with two exceptions. First, prior to the vertical spinal extension measure in the orchard, the subject performed a practice spinal extension. Since laboratory testing had shown that extremely low scores (11.34 kg or below) occur when the measure is performed incorrectly, proper performance was defined as obtaining a mean dynamometer reading (11.34 kg) as well as visually performing the measure properly. Second, before the first repetition of the arm hold measure in the orchard, the subject was instructed to raise the weight (4.54 or 2.27 kg depending on gender) over their head three times for 1 s in order to loosen the arm muscles and reduce the likelihood of cramping.

2.3. *Inclusion of data on subjects from an intervention belt trial*

Subsequent to the orchard testing of the timed arm hold and the standing spinal extension, these two measures were employed in research evaluating the efficacy of the hip belt intervention. Data from the control day measurement (placebo) of this study were added to this evaluation to increase sample size and improve precision. Use of these data for this purpose assumes that the placebo belt was identical to the condition of using their usual equipment. In order to check this assumption, statistical analyses of the difference in fatigue score between a "placebo equipment" workday, and a "regular equipment" workday was done on 20 subjects for whom data on both types of days had been collected. No significant differences were found.

2.4. *Data analyses*

As stated previously, the intent of the measure development trials was to identify strength measures that change significantly from pre- to post-work. To assess this, the null hypothesis that the fatigue scores for the working condition have mean equal to 0 was tested. The presence of a dose-response relationship was further considered through estimation of the correlation between hours worked and the magnitude of the fatigue scores. In this case, the null hypothesis that the value of this correlation was equal to zero was tested via conversion to Fisher's Z.

An additional analytic concern relates to the fact that the small sample size makes the central limit theorem relatively untenable for guaranteeing normality of the sampling distribution of the mean. Therefore, in cases where non-normality was suspected, non-parametric tests employing the median were used.

Considerable variability was observed due to varying degrees of effort put forth by the subject from repetition to repetition. Because of this, the maximum of the values observed over these repetitions was selected as the best indicator of a subject's muscle strength (Van Dieen et al., 2001).

For each subject, a difference score, defined as each day's maximum morning value minus the corresponding maximum afternoon value, was calculated. For example, the maximum of the three afternoon peaks for a given measure was subtracted from the maximum of the three morning peaks for this measure. Difference scores for the mean of this measure were calculated in an analogous manner.

In order to increase the interpretability of the results, all difference scores were expressed as a percent of the morning value

Endpoint = (maximum morning value−maximum afternoon value)/maximum morning value.

2.4.1. *Laboratory data analyses*

There were a total of nine difference scores for this trial: six for the latissimus dorsi raise (a mean and peak difference for each arm and for both arms together), and three times to failure results for the two timed arm holds and the spinal extension measure. All nine of these difference scores were expressed as a percent of the morning value.

Plots of the distributions of these percent difference scores were examined for normality and the presence of outliers. Since distributions were found to be normal, confidence intervals, (the mean +/−1.96 standard errors) were created for the averages of these mean and peak difference scores for each of the nine measures. Statistically significant differences were considered to be present for those intervals that did not contain zero.

2.4.2. *Orchard trial data analysis*

With the addition of the intervention trial placebo data ($n = 95$) to the orchard trial data ($n = 27$), the sample size was 102 subjects. As with the previous analysis, morning-to-afternoon strength differences were used to create fatigue scores, which were expressed as a percent of the morning value. This consisted of a mean and peak difference for the standing spinal extension, and the difference in time to failure for the dominant arm timed arm hold. Normally distributed fatigue scores not having outliers were analyzed using paired t-test analyses. When outliers were present, the median of the distribution of fatigue scores were taken as the measure of central tendency. A test of significance in this case was made using the Wilcoxon signed ranks test.

X–Y plots were created for each of the fatigue measures in order to examine the relationship between the magnitude of the fatigue score and the duration of hours worked between tests. Correlations between warm-up duration and fatigue score were also examined.

3. Results

3.1. Laboratory phase

In the laboratory, statistically significant fatigue between pre- and post-work measurements was found for two measures: the timed arm hold (35.7% reduction, 95% CI: 21.8–49.6), and the timed spinal extension (31.8% reduction, 95% CI: 23.5–40.0). The other tests were not significant (Table 2). All subjects had an elapsed time of 2 h, and had no warm-up interval.

3.2. Orchard phase

Table 3 shows selected demographic and physical characteristics of the study subjects who participated in this phase. The subjects were Jamaicans and Mexicans with varying preferences for bag carrying position (right, left, front). Additionally, there was a wide range of height, weight, and body mass index. However, analyses did not show associations between these variables and fatigue, so they were not considered in further analyses.

Subject warm-up times ranged from 28 to 240 min (mean: 97.4 minutes), and elapsed time between baseline and afternoon test ranged from 3 to 7.25 h (mean: 5.6 h). Correlations between warm-up time and fatigue as well as between elapsed time and fatigue were not statistically significant.

The mean fatigue score for the timed arm hold measure was 11.4% ($p<.0001$). For the standing spinal extension, median values were used as measures of central tendency for the distribution of both the peak and mean values, rather than means, due to the presence of outliers. A test of these medians employing the Wilcoxon signed ranks test showed neither to be significantly different from zero (Table 4).

4. Discussion

4.1. Laboratory phase

The laboratory data indicate that two measures are sensitive to one day of orchard harvest work: the timed arm hold (35.71% reduction, 95% CI: 21.81–49.61), and the timed spinal extension (31.75% reduction, 95% CI: 23.54–39.96). Thus, the hypothesis that laboratory measures of muscle fatigue could be identified was found to be valid.

4.2. Orchard phase

In contrast, the orchard workers showed a much smaller fatigue effect for the arm hold (11.4% $p<.0001$) and did not exhibit a significant fatigue effect for either measure (peak or mean) of the standing spinal extension. While the hypothesis for this phase was also not disproven, the results were much less conclusive.

With regard to the timed arm hold, one-day strength losses of between 10% and 30% are observed in other studies with moderate activity (Mullaney et al., 2005; Byrne

Table 3
Demographic characteristics of 102 subjects in trial four

Characteristic	*N*	
Mean age	99	42.6
% Male	99	97%
Jamaican	82	80%
Mexican	20	20%
Mean height	100	1.72 M (67.8 inch)
Mean weight	100	76.86 K (169.2 lb.)
Mean BMI	99	26.4
% Bag left side	9	9%
% Bag right side	15	15%
% Bag center	61	61%

Table 2
Pre- to post-work muscle strength differences for nine laboratory measures in trial two

Measure	*n*	Mean % drop	Std Err.	95% L	95% U
R-shoulder mean	8	3.51	8.46	−13.08	20.09
R-shoulder peak	8	2.81	6.16	−9.27	14.88
L-shoulder mean	8	3.29	2.93	−2.45	9.03
L-shoulder peak	8	1.62	2.39	−3.06	6.30
2-shoulder mean	8	9.35	5.64	−1.70	20.40
2-shoulder peak	8	10.11	5.49	−0.65	20.87
R-arm hold time	8	35.71*	7.09	21.81	49.61
L-arm hold time	7	9.31	8.34	−7.04	25.66
Timed spinal extension hold time	6	31.75*	4.19	23.54	39.96

*Statistically significant.

Table 4
Morning to afternoon fatigue scores for three tests among 102 apple harvest workers

		Mean % drop	P^*	Median % drop	p^{**}
Timed arm hold	102	11.38	<0.001	11.56	<0.0001
Standing spinal ext. mean	101	−8.42	.219	2.32	0.766
Standing spinal ext. peak	101	−.62972	.809	1.7056	0.659

*Paired *t*-test.
**Signed ranks test.

and Eston, 2002; Clarkson and Hubal, 2002). Other studies of strenuous activity have documented one-day drops ranging from 50–70% (Warren et al., 2002; Rinard et al., 2000; Howell et al., 1993). The results for the timed arm hold are therefore within the expected range for a functional measure of muscle fatigue. Similarly, an orthopedic physician with whom the authors conferred reported the use of 10% strength deficit as the threshold value for being indicative of injury (Jackson LaBudde, MD, personal communication, July 13, 2005).

There were some important differences between the laboratory trial and the orchard trial that may account for the smaller fatigue effect observed in the orchard for the timed arm hold. First, the laboratory subjects were not conditioned farmworkers. As a group, these eight volunteers were unaccustomed to apple harvest work, which would tend to make the fatigue effect more pronounced than it would be with actual farmworkers. This may have resulted in increased muscle fatigue among the laboratory subjects. On the other hand, the fact that the work interval in the laboratory was only 2 h (as opposed to 5 to 8 h in the orchard trial) would have led to less fatigue among subjects. It is difficult to say which is likely to have had a greater influence.

Another potentially important difference between the laboratory subjects and the orchard workers was the likely higher motivation level of the laboratory subjects to maximally exert themselves. As part of the research team, each of the laboratory volunteers was likely to be more motivated to perform the measures correctly and with maximum force. In contrast, some orchard worker subjects expressed concern regarding overtaxing themselves on the measures and a desire not to “tire themselves out,” a phenomenon that was not encountered in the laboratory. Reduced effort at baseline is likely to have led to an underestimation of fatigue.

The lack of a significant correlation between fatigue score and elapsed picking time between tests indicates that the fatigue effect seen in the timed arm hold does not follow a linear dose–response pattern. Further research would be needed to establish the presence of some non-linear dose–response pattern, or alternatively, an all or none response.

The inability of the standing spinal extension to detect fatigue (of 10% or more) in the orchard after a similar test (the timed spinal extension), detected a significant fatigue effect in the laboratory warrants further consideration. While the standing spinal extension measure was kept as similar to the timed spinal extension as possible, there were some major differences that may have affected the result. The fact that the timed spinal extension was held until failure and required the subject to hold against gravity may have been more effective in achieving a state of muscle fatigue where one day differences were observable. In contrast, pulling backwards for 5 s may have relied more on concentric muscle actions, which are much less prone to strain (Proske and Morgan, 2001).

In the literature, endurance-based measures are more commonly seen than those related to maximum strength (Stewart et al., 2003; Keller et al., 2001; Latimer et al., 1999; Bloswick and Mecham, 1994; Biering-Sorenson, 1983). On the other hand, two published studies suggest that maximum voluntary contraction measures (achieving a maximum rating on a dynamometer) are preferable because they are more reliable (Vollestad, 1997; Mayer et al., 1995).

Furthermore, there are a number of other factors that might affect a given muscle’s susceptibility to fatigue and strain: the muscle fiber type, the muscle length, overall size and structural complexity (Brooks, 2003; Proske and Morgan, 2001; Chaffin and Andersson, 1991). In order to fully take advantage of the logistical ease of mechanical field methods, it would be prudent to conduct further laboratory testing using surface electromyography to identify the most sensitive muscles, muscle groups and muscle actions.

5. Conclusions

Throughout the research, 12 different muscle strength measures were evaluated; four of these were timed endurance measures, and eight were maximum contraction measures (employing the dynamometer). While further research is needed to draw any firm conclusions, this preliminary data seems to suggest that endurance measures may be more effective in this setting than maximum strength measures. The fact that these measures diminished in the extent of fatigue detected from the laboratory (with researcher subjects) to the orchard (with worker subjects), may also be due to limitations of the physical environment, or to subject motivation and performance abilities.

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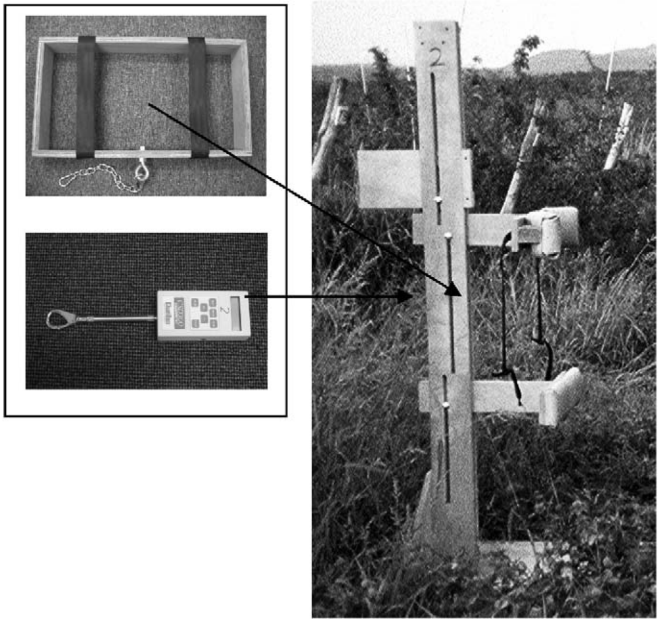
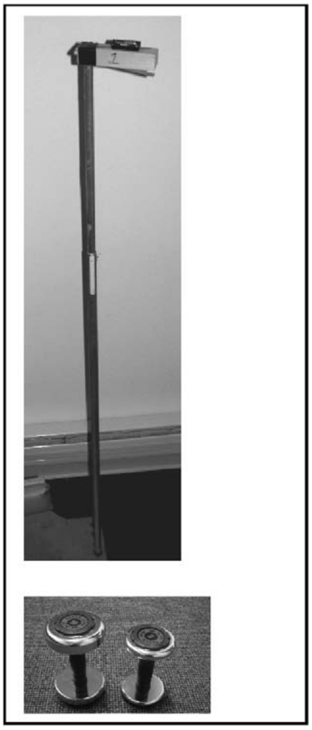
Appendix. Muscle testing equipment

Dynamometer: The Chatillon CSD 300 strength dynamometer manufactured by: Ametek Test and Calibration Instruments Division, 8600 Somerset Drive, Largo, FL 33773, (727) 536–7831. The dynamometer measures pulling force in pounds over a 5-s interval. It provides mean and peak pulling force for the interval. It stores mean and peak values for five, 5-s intervals and provides a coefficient of variation for all the tests stored in memory.



Dynamometer stand: This apparatus was custom-made by researchers to house the dynamometer for standing muscle tests. The tower is 1.83 m tall. The base is 0.66 m deep by 0.78 m wide. The stand has an adjustable dynamometer housing, so that the dynamometer can be located at the height of the subject's sternum, allowing for varying subject heights. In addition, the hip brace and knee brace are adjustable.



Dynamometer attachments for standing spinal extension—shoulder girdle, and dynamometer extension pin. Dynamometer attachments for timed arm hold, single arm—adjustable pole with contact light, 4.54 and 2.27 kg weights.

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