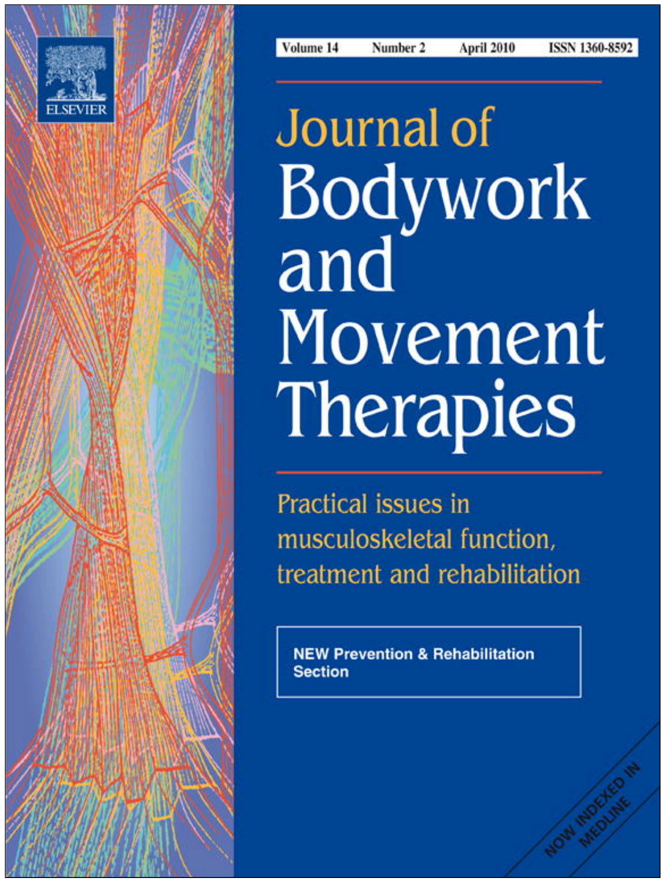
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ERGONOMICS

Proper body mechanics from an engineering perspective

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KEYWORDS
Massage;
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Summary The economic viability of the manual therapy practitioner depends on the number of massages/treatments that can be given in a day or week. Fatigue or injuries can have a major impact on the income potential and could ultimately reach the point which causes the practitioner to quit the profession, and seek other, less physically demanding, employment.

Manual therapy practitioners in general, and massage therapists in particular, can utilize a large variety of body postures while giving treatment to a client. The hypothesis of this paper is that there is an optimal method for applying force to the client, which maximizes the benefit to the client, and at the same time minimizes the strain and effort required by the practitioner.

Two methods were used to quantifiably determine the effect of using ''poor'' body mechanics (Improper method) and ''best'' body mechanics (Proper/correct method).

The first approach uses computer modeling to compare the two methods. Both postures were modeled, such that the biomechanical effects on the practitioner's elbow, shoulder, hip, knee and ankle joints could be calculated. The force applied to the client, along with the height and angle of application of the force, was held constant for the comparison.

The second approach was a field study of massage practitioners ($n = 18$) to determine their maximal force capability, again comparing methods using ''Improper and Proper body mechanics''. Five application methods were tested at three different application heights, using a digital palm force gauge.

Results showed that there was a definite difference between the two methods, and that the use of correct body mechanics can have a large impact on the health and well being of the massage practitioner over both the short and long term.

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Introduction

Massage therapy is a profession that can bring much needed relief to clients suffering from a variety of soft tissue injuries and illnesses. From pain associated with tight muscles, to joints that are dysfunctional due to physical activities, massage is a modality that is pursued by many people. The skilled massage therapist is the one who offers relief to such people's pain and suffering (Ernst and Fialka, 1994; Rich, 2002).

The irony is that in providing relief to others, many massage therapists cause injury to themselves. Sometimes in their zeal to help their client, they put themselves in an awkward posture and attempt to apply excessive degrees of force. Repetitive degrees of biomechanical load, commonly associated with poor body use, appears to affect many massage therapists, resulting in them leaving the profession (Greene, 1995).

In all occupations, it is important to use ergonomic principles when designing jobs involving muscle strength and movement (Kodak Ergonomics Group, 1987). The purpose of this paper is to explore how the use of body mechanics impacts the massage therapist, both physically and economically. The hypothesis is that proper body mechanics can lessen the chance of injury or illness, and the main approach will be to look at this issue from a scientific and an engineering perspective.

The need

According to 2007 data from the American Massage Therapy Association, there are approximately 267,000 people in the United States who are involved in the massage therapy profession. Based on their survey ($n = 838$ therapists), 15% are male and 85% are female, with an average of 6.5 years in the profession and an average age of 42. The average time actually performing (paid) massage is 15.1 h/week. There is an average turnover of 20% per year in the profession, and although more research is needed to determine the cause, 11% of respondents stated that avoiding personal injury was the top challenge facing massage therapists (AMTA, 2008). Since the majority of the massage population is female, data for the 50th percentile female will be utilized in all analyses using calculations or computer modeling.

The U.S. Bureau of Labor Statistics and the National Safety Council gather injury data from a variety of occupations. According to 2006 injury data for massage therapists (code 319010), 56% of the injuries were due to ''sprains/strains'', and 57% of the injury sources were from ''worker motion/position''. The upper extremities (including hand/wrist) accounted for 51% of the injuries, followed by the trunk at 16%. (See Appendix A for a breakdown of all the massage therapist injury statistics.)

The human body as a system of levers and pulleys

The human body is composed of muscle, bone, tendons and ligaments, all of which make up its load bearing and force generating components. In engineering terms, these components can be equated to levers, fulcrums, pulleys, etc. Some massage therapy textbooks (Fritz, 2009a) make reference to these terms, but, to our knowledge, no one has made an attempt to actually calculate the forces involved with massage, to mathematically show the advantages of using proper body mechanics.

To understand the forces that occur at the joints of the human body, a brief description and example is necessary.

The one main descriptor of any joint in the human body is movement, more specifically rotational movement. A ''moment'' is an engineering term used to defined rotational movement around an axis. This term adequately describes the forces that occur at a joint. For example, in order to hold a weight in one's hand with the forearm parallel to the ground, there are two forces trying to rotate the arm in a downward motion, and simplistically speaking one counteracting force trying to rotate the forearm upward, thus keeping it steady. The two downward forces are the weight of the forearm (including the hand) and the weight of the load being held. The upward, stabilizing force, comes from the muscles of the upper arm (biceps brachii and brachialis). Figure 1 (Chaffin et al., 2006) shows what happens at the elbow joint when this occurs.

A moment is calculated by multiplying the force acting on a rotational axis (in this case the pivot point of the elbow) with the distance that force is from the axis. Using the anthropometry for a 50th percentile female, the total distance from the elbow joint to the center of the hand is 12.2 inches (~31 cm), and the center of mass (CM) of this arm/hand segment is 5.3 inches (~13.5 cm) from the elbow. The weight of this body segment is 3.0 pounds (1.35 kg). If a person were holding a load of 20 pounds (~9 kg) in the hand, the downward moment created at the elbow would be:

$$
\begin{aligned}
M(\text{elbow}) &= (5.3\ \text{inch} \times 3.0\ \text{lb}) + (12.2\ \text{inch} \times 20\ \text{lb}) \\
&\ (\mathbf{13.5\ cm} \times \mathbf{1.35\ kg}) + (\mathbf{31.0\ cm} \times \mathbf{9.0\ kg}) \\
M(\text{elbow}) &= 15.9\ \text{inch-lb} + 244.0\ \text{inch-lb} \\
&\ \mathbf{18.2\ cm\text{-}kg} + \mathbf{279.0\ cm\text{-}kg} \\
M(\text{elbow}) &= 259.9\ \text{inch-lb} \\
&\ \mathbf{297.2\ cm\text{-}kg}
\end{aligned}
$$

If the arm is stationary, then the counteracting moment of the muscle must also equal 259.9 inch-pounds (297.2 cm-kg). Knowing that the attachment point for the biceps brachii and brachialis muscles is 1.97 inches (5.0 cm) from the rotational axis of the elbow, the muscle force required to hold this load can be calculated as follows:

$$
\begin{aligned}
F(\text{muscle}) &= 259.9\ \text{inch-lb} / 1.97\ \text{inch} \\
&\ \mathbf{297.2\ cm\text{-}kg} / \mathbf{5.0\ cm} \\
F(\text{muscle}) &= 132\ \text{lb} \\
&\ \mathbf{59.4\ kg}
\end{aligned}
$$

Thus, in this example, it takes 132 pounds (59.4 kg) of muscle force to hold a 20 pound (9.0 kg) object in the hand. This information can then be compared to research which was conducted to determine population muscle strength moments (Stobbe, 1982), in order to determine the percent of the given population that could withstand this rotational force on the elbow.

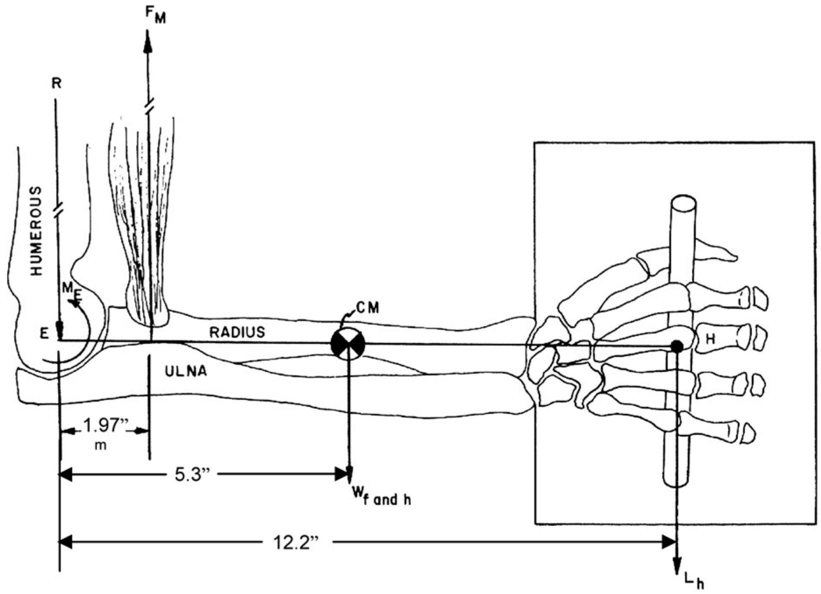


Figure 1 Free body diagram of the forces acting on the elbow joint while holding a load in the hand. M_E is the sum of the moments at the elbow, determined by the load in the hand (L_H), weight of the forearm and hand ($W_{F\&H}$), the force of the muscle (F_M), and the attachment distance of the muscle (m). (From Chaffin et al., 2006, p. 116, used by permission).

As can be seen, even this most basic calculation can be very complex. As one starts to work further through the body, all the forces acting on the elbow, in addition to those acting on the upper arm, come into play to calculate the shoulder moments. Calculations for the hip, knee and ankle become increasingly complex. Also, this example is two-dimensional, and all forces are acting at 90 degrees. In the real world, postures are three-dimensional and forces act at varying angles, requiring a great deal of trigonometry to make the calculations.

The above description is provided to show that it is possible to determine the effect that a given posture and forces can have on the human body. Fortunately, there is human modeling software available that can make all of these calculations and compare the results to the strength moment data for the population selected. However, it must be noted that both the above calculations and the modeling software make assumptions about the human anatomy and function. All of the complex dynamics of human motion (such as the affect of synergistic muscles) cannot be completely accounted for, but these models can provide a good approximation, especially for comparative purposes. This human modeling software will be utilized to make the comparisons between proper and improper body mechanics in a later section.

Proper body mechanics — general concepts

All massage therapists, to varying degrees, learn how to apply forces to their clients in order to affect some neurological, physiological or mechanical change. Some schools may also teach the therapist how to use their body in order to make the massage visually appealing by giving it a certain flow. However, very few schools teach the therapist how to use their body in a manner that will reduce the chance of the therapist becoming fatigued and possibly injured over the long term.

Fritz (2009b) dedicates a chapter to the use of proper body mechanics. Some of these concepts will be discussed in order to understand, and ultimately compare the effects of body mechanics.

Whenever the body utilizes muscle force, energy must be expended. When a joint is stacked (in straight alignment), forces acting on the joint go straight through, and do not generate any rotational force that must be counteracted by the muscle. The other key principle in massage is that body weight and gravity are free. Making movements in a downward direction, the weight of the body can be used to increase the force (Konz, 1995). Normally, whenever the center of gravity of the body moves past the base of the feet, some muscles contract to counteract and stabilize the body. However, when that force generated by body weight can be transferred through the hand onto another stationary object, this force transfer requires only minimal muscle activity. Also, since the majority of the force is generated through body weight, the force can be applied for a longer time period without generating undue fatigue. This can be achieved by ''stacking'' body segments in such a way that the rotational effects of moments at the joints are minimized and the majority of force is applied through body weight (Figure 2).

Proper body mechanics — computer modeling approach

As was shown in the section on ''The human body as a system of levers and pulleys'', the forces acting on the

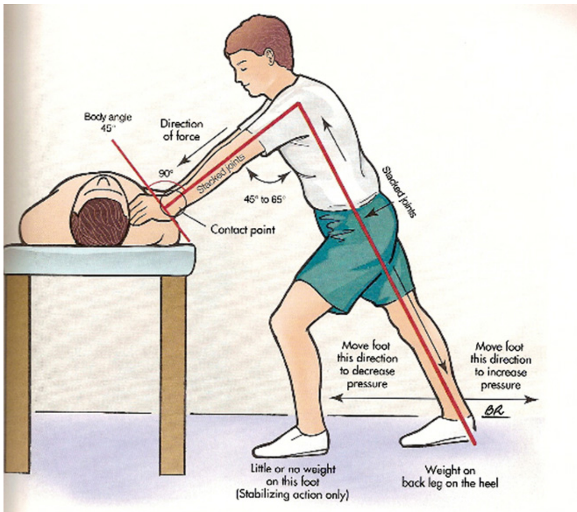


Figure 2 Diagram of stacked joints (from Fritz, 2009b, p. 224).

joints of the body can be mathematically calculated and these calculations can by aided by existing computer software models. The University of Michigan 3D Static Strength Prediction Program™ (3DSSPP™) was utilized to compare what was hypothesized to be ''Improper'' versus ''Proper'' body mechanics in a massage application. The following photographs (Figure 3) show two contrasting methods for applying a compressive force to a client.

The ''Improper'' posture in Figure 3a, the massage practitioner is standing in a more upright posture and bending at the torso, at approximately 55 degrees. The left elbow is bent, thus requiring a majority of the force to be exerted using arm strength, and causing a rotational movement (moment) at the elbow joint. In contrast, the ''Proper'' posture in Figure 3b, shows the massage practitioner using ''stacked joints'' where the opposite leg, torso, neck and head are in alignment. The force generating arm is also straight, transferring the force straight through the elbow joint and thus not requiring any additional muscle force to counteract a rotational movement. Instead of using arm strength as in the previous posture, the practitioner can lean on the client and thus use her body weight to assist in generating the majority of the force applied to the client.

The massage practitioner's posture (body segment angles) was loaded into the 3DSSPP™ software, using the anthropometry of the 50th percentile female and the applicable muscle strength moments. The computer generated posture output is shown for both postures in Figure 4 and the free body diagram of the joint segment analysis in Figure 5.

A load of 40 pounds ($\sim$18.2 kgm) was chosen as the compressive force to be applied to the client, applied at a height of 33.3 inch (84.5 cm) and at a downward angle of 45 degrees. Utilizing these two postures with the same magnitude and angle of force, capabilities were calculated for the elbow, shoulder, hip, knee and ankle joints. The actual computer results are shown in Appendix B, and are summarized here in Table 1.

Whereas 99% of the selected female population has the capability to generate the necessary strength moments at all of the joints using the ''Proper'' body mechanics posture, only 40% has the capability using the ''Improper'' posture, with the limiting factor being the ankle joint. (Note: because the ankle cannot be rotated in the 3D Program, small weight and balance adjustments that a person would use are difficult to model, thus the results for the ankle should be used with caution). The elbow was also a significant limiting joint, with only 60% having the required capability. In addition, the ''Improper'' posture put 13% more compressive force on the L5/S1 joint.

Proper body mechanics — field study approach

In addition to the 3D modeling discussed above, a strength test protocol was developed to test three different applications of body mechanics. Eighteen (18) massage practitioners, with varying levels of experience (normal distribution with median of 2–3 years — see Table 2), were asked to apply a compressive force using what was hypothesized to be ''Poor'' (standing arm push), ''Good'' (stacked joints but without locking the back knee), and ''Best'' (stacked joints with a locked back knee) body mechanics. Applications using counterpressure were also recorded for the ''Poor'' and ''Best'' positions. (Note: in this study, the ''Poor'' and ''Best'' postures, correspond to the ''Improper'' and ''Proper'' postures used in the computer modeling section).

The subjects were outfitted with an Ergo-FET digital palm force gauge, which could record a maximum force of 150 pounds ($\sim$68 kg) (see Figure 6). Static strength assessments must be kept to less than 10 s to keep from fatiguing the muscle, with the recommended duration being between 4 and 6 s (Sanders and McCormick, 1993). All test durations were less than 10 s, with the majority being within the recommended range.

The subjects were tested applying compressive force at a 45 degree angle to the edge of massage tables, at vertical heights of 39.5 inch (100 cm), 34.5 inch ($\sim$87.5 cm), and 29.0 inch ($\sim$73.5 cm) (see Figure 7). The surfaces were wooden frames, covered with a thin layer of foam and a vinyl covering.

All subjects had been previously trained in the use of the ''Good'' and ''Best'' postures. For the ''Poor'' posture (Figure 7a), the subjects were instructed to stand at a comfortable location from the table, and to apply maximal pressure by pushing with their arm. The subjects were intentionally not given more than this general instruction, so as to allow them to find their most natural position. There was a tendency to still lean in with the body to some degree, thus pure arm strength forces would be generally even lower than recorded. Five data points were collected at each of the three vertical heights. These data points were as follows.

(A) Standing arm push (Figure 7a)
(B) Standing arm push with counterpressure
(C) Stacked joints, not locking the knee
(D) Stacked joints, with locked knee (Figure 7b)
(E) Stacked joints, with locked knee and counterpressure

The raw data collected are shown in Table 2, with references A–E corresponding to the above postures.

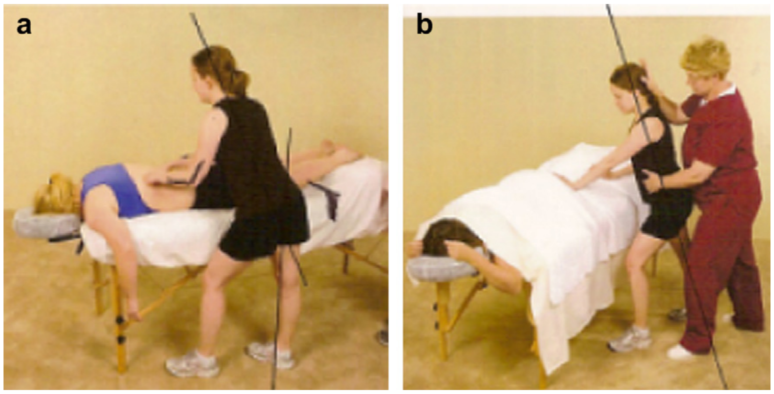


Figure 3 Photographs of two contrasting methods for applying compressive force to a client. (a) Improper method. (b) Proper method.

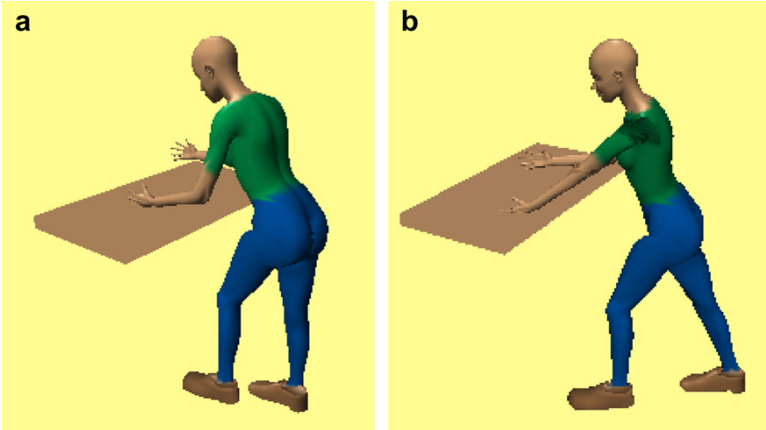


Figure 4 Computer modeling of application methods (from University of Michigan 3DSSPP™, ver. 5.0.8, used by permission). (a) Improper method. (b) Proper method.

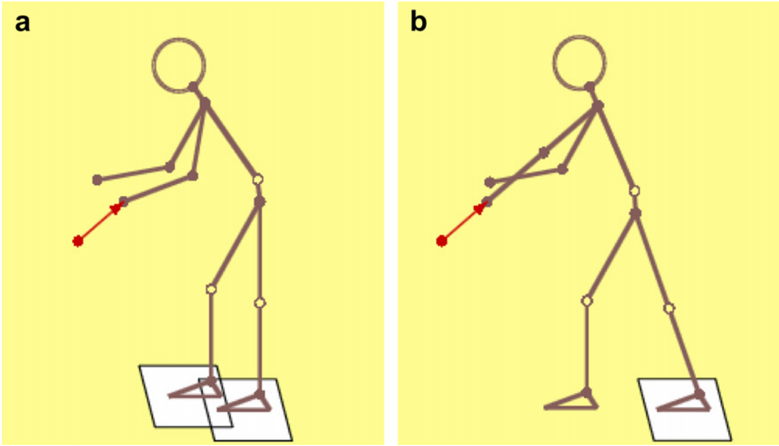
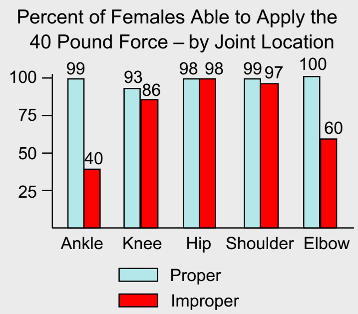


Figure 5 Computer modeling of application methods (from University of Michigan 3DSSPP™, ver. 5.0.8, used by permission). (a) Improper method. (b) Proper method.

Table 1 Results from computer modeling analysis, comparing the Proper and Improper methods.



Compression Force on the L5/S1 Disk:	Proper	91 lbs.
	Improper	103 lbs.

Summary of analysis results from The University of Michigan 3D Static Strength Prediction Program™

Comparisons were performed using the average forces generated at each of the three table heights (Table 3), and using the combined averages for all three tests (Table 4). The results in both tables are interpreted as follows. A percentage figure in the table compares the description in the column on the left with the row description above. Using for example ''standing arm push'' (poor) versus ''stacked and locked'' (best) at a height of $H = 39.5$ inch ($\sim$100 cm), the arm push posture averaged 32.5 pounds ($\sim$14.7 kg) and the stacked and locked posture averaged 49.0 pounds ($\sim$22 kg). By looking in the table at the intersection of these two postures, it shows that this comparison generated 51% more force for the stacked and locked posture.

Table 3 compares the effects of the different test heights. Test 1 (with $H = 39.5$ inch ($\sim$100 cm)) has the largest percentage increases in all categories. By contrast Test 3 (with $H = 29.0$ inch ($\sim$73.5 cm)) has the smallest percentage increases in all categories. Thus, while proper

Table 2 Raw data showing subject's years of massage experience (also see distribution below table), height, and weight. Data within the table are maximum applied forces recorded (in pounds) at the three test heights using the five application methods (A–E). The last three rows contain the average, minimum and maximum force for each column ($n = 18$).

Demographics			Test 1: $H = 39.5$ inch					Test 2: $H = 34.5$ inch					Test 3: $H = 29.0$ inch				
Years	Height (inches)	Weight (lb.) (1 inch = 2.54 cm; 1lb = .45 kg)	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
2–3	62	145	25	48	26	32	63	36	56	31	40	72	58	67	44	51	72
2–3	63	130	31	47	35	41	58	53	55	48	59	68	63	68	68	70	73
0–1	63	170	17	26	18	28	28	18	35	25	31	40	33	41	39	42	49
>5	63	173	32	73	38	42	87	40	71	44	45	88	48	64	55	58	89
2–3	64	130	21	75	51	59	104	28	80	43	56	82	46	88	48	59	98
1–2	65	125	26	52	34	46	61	45	70	51	53	77	54	64	57	51	59
3–5	66	185	47	84	65	78	92	62	86	71	80	84	72	93	75	86	83
1–2	66	130	40	48	30	46	61	52	69	46	50	70	61	72	51	53	62
2–3	66		32	66	52	64	71	49	77	48	57	78	40	68	70	71	73
3–5	66	170	30	56	25	43	73	28	65	33	44	57	28	48	32	47	57
1–2	66	285	60	68	45	70	82	55	66	63	69	76	67	69	76	89	97
2–3	67	130	39	61	50	48	81	36	56	38	49	66	39	62	49	51	78
0–1	67	170	22	35	33	38	49	26	43	31	42	61	34	49	35	45	59
3–5	67	165	32	42	29	39	60	35	43	38	42	59	36	38	37	54	77
>5	67	205	32	34	34	43	67	29	40	32	41	69	48	60	46	58	71
2–3	72	150	42	82	52	56	97	47	79	58	69	95	57	87	59	66	95
2–3	69	165	24	69	35	50	71	35	57	40	51	74	32	48	33	40	51
2–3	68	140	33	55	39	59	96	34	62	52	62	98	49	76	59	75	110
Average	66	163	32.5	56.7	38.4	49.0	72.3	39.3	61.7	44.0	52.2	73.0	48.1	64.4	51.8	59.2	75.2
Minimum	62	125	17	26	18	28	28	18	35	25	31	40	28	38	32	40	49
Maximum	72	285	60	84	65	78	104	62	86	71	80	98	72	93	76	89	110

Years of massage experience	0–1	1–2	2–3	3–5	>5
Number of subjects	2	3	8	3	2

Figure 6 Photo of Ergo-FET digital palm force gauge.

body mechanics allow the subject to generate higher forces in all cases, it has the most impact when the point of application is higher off the floor.

Overall comparisons for the data are in Table 4, and can be summarized as follows. Tables are in Imperial measures: to convert to decimal use 2.54 cm = 1 inch, and 0.45 kg = 1 pound/lb)

- Counterpressure increases forces for both methods (standing arm push increases by 53% and stacked and locked increases by 37%)
- Counterpressure is higher with proper body mechanics (by 21%)
- Stacked and locked (best) body mechanics is better than stacked not locked (good) body mechanics (by 20%)
- Stacked not locked (good) and stacked and locked (best) are both better than standing arm push (poor) body mechanics (by 12% and 34%, respectively)

Proper body mechanics — general tips for massage therapists

Although the main purpose of this paper is to validate the concept that proper body mechanics do indeed reduce stress on the massage practitioner, it would be remiss to leave the topic without providing some useful suggestions. Fritz (2009b) dedicates an entire chapter in her book explaining and demonstrating various techniques. The following is a very brief summary of some of the major concepts. Referring back to Figure 2, in addition to the photos in Figure 8, will assist in visualizing these concepts.

Weight transfer

Leveraging body weight, as opposed to utilizing muscle force, will significantly reduce the stress on the practitioner. Pushing with upper body strength can cause neck and shoulder problems. Stand in an asymmetric stance with the back leg and torso in a straight line, keep the hips and shoulders aligned and facing the client, and lock the back knee to generate pressure coming from the back heel. Note how in Figure 8a, the table is too low causing the therapist to rock back and bend at the waist. In Figure 8b, the higher table allows the therapist to leverage all of his body weight. Also, Figure 8e shows the therapist's weight improperly on the front foot, versus the proper posture in Figure 8g with the pressure coming from the back heel.

Perpendicular application of force

Align the client and practitioner such that force is applied at a 90 degree angle. This makes the force application more efficient by directing 100% of the pressure into the client's tissue (refer back to Figure 2).

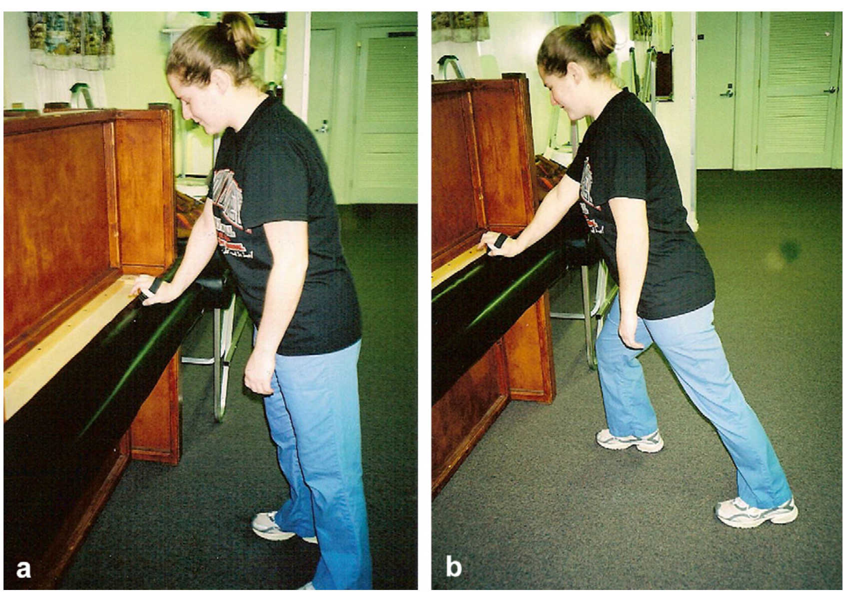


Figure 7 Photo of test subject performing: (a) poor posture and (b) best posture at 34.5 inch test height.

Table 3 Comparison of force differentials at each test height, presented as a percentage (1 inch = 2.54 cm; 1lb = .45 kg).

	Standing arm push	SAP with C/pressure	Stacked not locked	Stacked and locked	S and L with C/pressure
Test 1: $H = 39.5$ inch					
Compression force (lbs.)	32.5	56.7	38.4	49.0	72.3
Standing arm push		75%	18%	51%	
SAP with C/pressure					27%
Stacked not locked				28%	
Stacked and locked					48%
Test 2: $H = 34.5$ inch					
Compression force (lbs.)	39.3	61.7	44.0	52.2	73.0
Standing arm push		57%	12%	33%	
SAP with C/pressure					18%
Stacked not locked				19%	
Stacked and locked					40%
Test 3: $H = 29.0$ inch					
Compression force (lbs.)	48.1	64.4	51.8	59.2	75.2
Standing arm push		34%	8%	23%	
SAP with C/pressure					17%
Stacked not locked				14%	
Stacked and locked					27%

Stacked joints

As discussed previously, joints that are not stacked and locked require additional muscle force to hold the joint steady and counteract rotational forces in the joint while applying pressure (refer to Figure 8c–g).

Core stability

Having good core stability is essential to eliminate fatigue and possible injury. If the core is not working, the psoas and rectus abdominis take over core responsibility. Also, the body over breathes in order to cause the lumbar dorsal fascia to tighten, in an attempt to stabilize the core.

Point of contact

The practitioner must use caution to protect their hands and wrists. Whenever possible, force should be applied using the forearm. If the hand is used, the wrist should remain in the mid-range of motion, avoiding any extreme extension of the wrist which puts undue stress on the structures of the carpal tunnel. The hand and fingers should be relaxed whenever possible, to keep from transferring stress to the forearm and shoulder.

Economic impact

There is no current research which delves into why approximately 50,000 massage therapists leave the profession each year, in the USA (AMTA, 2008). As was stated earlier, the majority of the injuries which require massage therapists to lose time from work are related to ''sprains and strains'', and the most common cause is ''worker motion or position''. Also, 11% of therapists surveyed cite ''avoiding personal injury'' as their top challenge in the profession. Since the use of proper body mechanics has been shown to reduce the strain on the therapist's body and improve their motions and positions, the data suggest that there is some number of therapists who have left the profession due to injury, who would still be working today if they had used proper body mechanics.

The ramifications are personal injury and loss of income (especially since very few massage therapists have health benefits from their employers or are self-employed). The

Table 4 Comparison of the average force differentials from all test heights, presented as a percentage.

	Composite averages at all heights (1 inch = 2.54 cm; 1lb =.45 kg)				
	Standing arm push	SAP with C/pressure	Stacked not locked	Stacked and locked	S and L with C/pressure
Compression force (lbs.)	40.0	60.9	44.7	53.5	73.5
Standing arm push		53%	12%	34%	
SAP with C/pressure					21%
Stacked not locked				20%	
Stacked and locked					37%

Figure 8 Examples of correct vs. incorrect postures (from Fritz, 2009b, pp. 217–237).

economic impact can also affect the profession in a more subtle way. If strain and soreness from improper body mechanics is the limiting factor in the number of clients that a therapist can see on a daily basis, then the use of proper body mechanics can increase their daily output. Using an industry average of 15 paid massages per week (in the USA), and an average wage of $39 per hour (AMTA, 2008), and assuming a therapist works 5 days per week (equating to 3 massages per day) and 48 weeks per year, the therapist would theoretically make $28,080 per year. If the therapist, by improving their body mechanics, could increase their workload by only 1 client per day, their annual income could increase by $9360 to a total of $37,440. If they could now physically perform 2 additional massages per day the annual income would be $46,800, an increase of $18,720.

Further research would be required to put an exact number on the injured therapists leaving the profession and the potential for increased client workload, as well as the impact that proper body mechanics would have. However, there is enough data here to suggest that a relationship does exist, and for the good of the profession it is one that should be explored further.

Summary

Poor body mechanics can affect both the client and the practitioner. If a certain amount of compressive force is required to deal with the client's symptoms, and the massage practitioner cannot deliver that force, then the client's treatment will not be as effective as possible. If the practitioner can deliver the required force, but they are working at or near their maximum strength, then the practitioner may suffer either an acute or chronic injury.

The physical effects of the massage on the massage practitioner can be quantified. In the computer modeling comparison, use of the improper posture showed that only 40% of the 50th percentile female population would have the strength moment capability at the ankle, and only 60% would have the capability at the elbow. In contrast, using proper body mechanics, that same population would have 99% capability at the ankle and 100% capability at the elbow. All other joints showed the same trend, but the range of capability was less significant.

In the field study of massage practitioners ($n = 18$), it was found that proper body mechanics correlated with an overall 34% increase in applied maximal force, as compared with the improper posture. When counterpressure was used with both postures, the increase was 21%. This trend held true for all three test heights, with the impact of using proper body mechanics being greatest at the highest point of application.

However, one cannot use the actual dimensions used in this study to set a table height. The practitioner must evaluate their own body type and massage style (majority hand or forearm work) and make adjustments accordingly.

Key concepts

Certain general concepts assist in the application of good body mechanics. A few of these concepts are as follows.

- Leveraging body weight as opposed to using muscle force
- Applying forces at 90 degree angles
- Stacking joints to avoid rotational forces in the joints
- Locking the back knee and pushing from the heel to generate more force
- Application of force using the forearm wherever possible and keeping the hand and fingers relaxed
- Keeping the wrist within the mid-range of motion when necessary to use the hand to apply force
- Having a good breathing pattern and core stability.
- Although not proven, the data suggest that the reduced strain from proper body mechanics can have a positive effect on the therapist's economic well being, either from the ability to increase client workload, or from the ability to avoid injury and stay in the profession.
- Setting the correct massage table height, and using proper body mechanics, will allow the massage/manual therapy practitioner to generate higher compressive forces, while at the same time using less force and strain on their own body.

Appendix A

Injury data for massage therapists from the U.S. Department of Labor (2006), Bureau of Labor Statistics (http://www.bls.gov/iif/oshwc/osh/case/ostb1801.pdf) and the National Safety Council. Note: data reformatted by author.

Number of nonfatal occupational injuries and illnesses involving days away from work. Source: National Safety Council, 2006 data for Massage Therapists, based on data from the U.S Department of Labor, Bureau of Labor Statistics (code 319010).

Sex	Age	Race	Length of service
32% Men	47%, 25–34	48% White	14%, <3 months
68% Women	32%, 35–44	14% Hispanic	14%, 3–11 months
	21%, 45–54	38% Not reported	32%, 1–5 years
			41%, >5 years
Injury	**Event or exposure**	**Injury source**	**Time of day**
56% Strain/sprain	26% Overexertion	57% Worker motion/position	19%, 8:00 am–12:00 pm
22% Soreness, pain	26% Repetitive motion	10% Ground, floor surfaces	19%, 12:00 pm–4:00 pm
11% Carpal tunnel	11% Contact with object	10% Patient	14%, 4:00 pm–8:00 pm
11% Other	37% Other	24% Other	48%, Not reported

(*continued on next page*)

Table (*continued*)

Body part affected	Hours worked	Time off-work	Day of week
35% Upr. extremities	10%, <1 h	10%, 2 days	14% Monday
19% Wrist	0%, 1–2 h	15%, 3–5 days	14% Tuesday
16% Trunk	10%, 2–4 h	15%, 6–10 days	18% Wednesday
10% Lwr. extremities	10%, 4–6 h	20%, 11–20 days	23% Thursday
6% Hand	15%, 6–8 h	15%, 21–30 days	14% Friday
6% Shoulder	55%, Not reported	25%, >31 days	18% Saturday
6% Back			
$n = 220$			

Incidence rate of nonfatal occupational injuries and illnesses involving days away from work. Injuries per 10,000 workers

Injury	Event or exposure	Injury source	Body part affected
44.8 Strain/sprain	21.3 Overexertion	50.2 Worker motion/position	25.9 Wrist
17.3 Soreness, pain	21.0 Repetitive motion	10.1 Patient	13.4 Lwr. extremities
8.2 Carpal tunnel	7.7 Contact with object	7.1 Ground, floor surfaces	11.0 Upr. extremities
8.4 Other	30.9 Other	22.9 Other	10.0 Hand
			8.3 Back
			7.2 Shoulder
			4.5 Trunk

In 2006, there were 1.2 million cases requiring days away from work in private industry.
The 2006 rate for all industries was 128 per 10,000 workers.
The 2006 rate for massage therapists was 93.8 per 10,000 workers.
Rates ranged from 11 (computer and mathematical) to 301 (transportation and material moving).

Appendix B

Joint capability data from University of Michigan 3D Static Strength Prediction Program™ (3DSSPP™), used by permission

1) 3DSSPP™ analysis summary

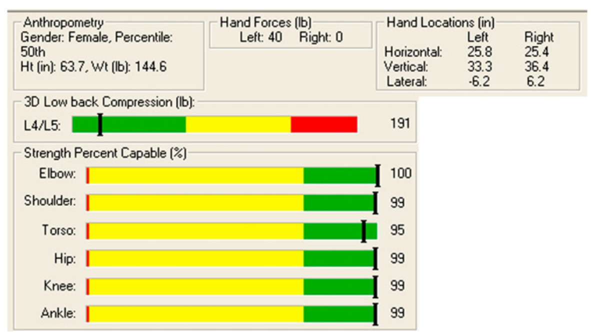


Figure B1b Proper method.

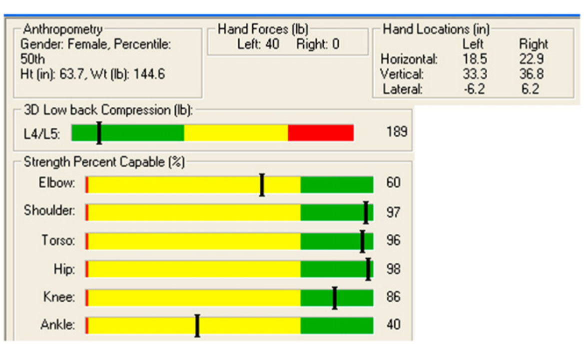


Figure B1a Improper method.

2) Low back analysis — sagital plane

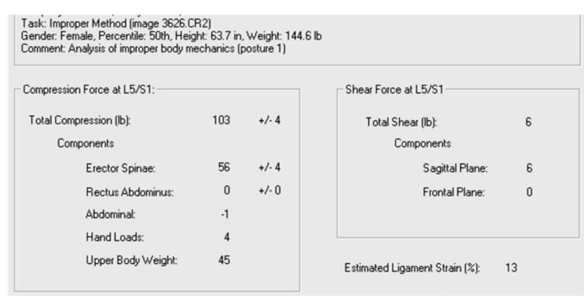


Figure B2a Improper method.

Task: Proper Method (image 3241.CR2)
Gender: Female, Percentile: 50th, Height: 63.7 in, Weight: 144.6 lb
Comment: Analysis of proper body mechanics (posture 1)

Compression Force at L5/S1:		
Total Compression (lb):	91	+/- 12
Components		
Erector Spinae:	0	+/- 0
Rectus Abdominus:	46	+/- 12
Abdominal:	-4	
Hand Loads:	2	
Upper Body Weight:	47	

Shear Force at L5/S1	
Total Shear (lb):	4
Components	
Sagittal Plane:	4
Frontal Plane:	0

Estimated Ligament Strain (%): 10

Figure B2b Proper method.

3) Strength capabilities

Task: Improper Method (image 3626.CR2)
Gender: Female, Percentile: 50th, Height: 63.7 in, Weight: 144.6 lb
Comment: Analysis of improper body mechanics (posture 1)

Capabilities

		Left					Right				
		Required		Population Strength			Required		Population Strength		
		Moment (in-lb)	Muscle Effect	Mean (in-lb)	SD (in-lb)	Cap (%)	Moment (in-lb)	Muscle Effect	Mean (in-lb)	SD (in-lb)	Cap (%)
Elbow Flex/Ext		151	EXTEN	166	54	60	-16	FLEXN	322	85	100
Shoulder	Humeral Rot	0	------	----	----	100	0	------	----	----	100
	Rot'n Bk/Fd	0	------	----	----	100	0	------	----	----	100
	Abduc/Adduc	-161	ABDUCT	339	89	97	-46	ABDUCT	364	96	99
Torso	Flex/Ext	-120	EXTEN	1700	587	99					
	Lat'l Bending	19	LEFT	1983	486	100					
	Rotation	248	RIGHT	528	160	96					
Hip Flex/Ext		132	FLEXN	1272	428	99	-161	EXTEN	920	348	98
Knee Flex/Ext		0	------	----	----	100	335	EXTEN	547	190	86
Ankle Flex/Ext		0	------	----	----	100	784	FLEXN	736	202	40

Figure B3a Improper method.

Task: Proper Method (image 3241.CR2)
Gender: Female, Percentile: 50th, Height: 63.7 in, Weight: 144.6 lb
Comment: Analysis of proper body mechanics (posture 1)

Capabilities

		Left					Right				
		Required		Population Strength			Required		Population Strength		
		Moment (in-lb)	Muscle Effect	Mean (in-lb)	SD (in-lb)	Cap (%)	Moment (in-lb)	Muscle Effect	Mean (in-lb)	SD (in-lb)	Cap (%)
Elbow Flex/Ext		-12	FLEXN	251	66	100	-16	FLEXN	328	86	100
Shoulder	Humeral Rot	0	------	----	----	100	0	------	----	----	100
	Rot'n Bk/Fd	0	------	----	----	100	0	------	----	----	100
	Abduc/Adduc	-58	ABDUCT	368	97	99	-46	ABDUCT	369	97	99
Torso	Flex/Ext	115	FLEXN	557	221	97					
	Lat'l Bending	68	LEFT	1577	386	100					
	Rotation	239	RIGHT	502	152	95					
Hip Flex/Ext		132	FLEXN	1316	443	99	84	FLEXN	1272	428	99
Knee Flex/Ext		0	------	----	----	100	-21	FLEXN	792	254	99
Ankle Flex/Ext		0	------	----	----	100	-171	EXTEN	895	246	99

Figure B3b Proper method.

4) Fatigue analysis

Task: Improper Method (image 3626.CR2)
Gender: Female, Percentile: 50th, Height: 63.7 in, Weight: 144.6 lb
Comment: Analysis of improper body mechanics (posture 1)

		Left			Right		
		Required Percent MVC			Required Percent MVC		
Population Strength Percentile		5	25	50	5	25	50
Elbow Flex/Ext		194	116	91	9	6	5
Shoulder	Humeral Rot	0	0	0	0	0	0
	Rot'n Bk/Fd	0	0	0	0	0	0
	Abduc/Adduc	84	58	47	22	15	13
Torso	Flex/Ext	16	9	7			
	Lat'l Bending	2	1	1			
	Rotation	93	59	47			
Hip Flex/Ext		23	13	10	46	23	17
Knee Flex/Ext		0	0	0	142	80	61
Ankle Flex/Ext		0	0	0	194	131	106

Figure B4a Improper method.

Task: Proper Method (image 3241.CR2)
Gender: Female, Percentile: 50th, Height: 63.7 in, Weight: 144.6 lb
Comment: Analysis of proper body mechanics (posture 1)

		Left			Right		
		Required Percent MVC			Required Percent MVC		
Population Strength Percentile		5	25	50	5	25	50
Elbow Flex/Ext		9	6	5	8	6	5
Shoulder	Humeral Rot	0	0	0	0	0	0
	Rot'n Bk/Fd	0	0	0	0	0	0
	Abduc/Adduc	28	19	16	22	15	12
Torso	Flex/Ext	59	28	21			
	Lat'l Bending	7	5	4			
	Rotation	95	60	48			
Hip Flex/Ext		22	13	10	15	8	7
Knee Flex/Ext		0	0	0	6	3	3
Ankle Flex/Ext		0	0	0	35	24	19

Figure B4b Proper method.

Appendix C

Computer software

3D Static Strength Prediction Program™, version 5.0.8, copyright© 2007, The Regents of the University of Michigan 2007, used with permission.

Equipment

Ergo-FET digital palm force gauge, Hoggan Health Industries.
Serial #22153 — Patent #5090421.
150# maximum capacity.
New unit, calibrated 4 months prior by manufacturer.

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