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Biomechanical assessment of massage therapists

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Abstract. This study was undertaken to investigate the biomechanical demands on the low back of Massage Therapists performing typical massage therapy techniques and the nature of the associated cumulative exposure. Ten Massage Therapists performed a standardized relaxation back massage that incorporated a series of basic massage therapy techniques used in standard treatments. The 44-minute massage treatment was videotaped and a posture-matching approach was used to determine 3D peak and cumulative loads on the low back. Although the resultant peak low back loads would be considered safe in relation to current published compression and shear guidelines, the cumulative loading values were well within the ranges considered disconcerting in other health care and industrial workers. The therapists were found to assume non-neutral trunk, neck and arm postures for a significant portion of the massage, which could place these professionals at risk of cumulative musculoskeletal disorders.

Keywords: Massage therapy, cumulative loading, peak loading, posture analysis

1. Introduction

For years, low back pain (LBP) and upper extremity musculoskeletal disorder (MSD) research has focused on industrial workers due to its documented relationship to manual material handling (MMH) activities such as lifting. More recently, investigations into healthcare professions such as nursing [15, 28,30], paramedics and ambulance attendances [13] and physiotherapists [27] have revealed alarmingly high incidence of LBP reporting. Lifetime prevalence of LBP, for example, has been reported to be between 45–80% in nursing [3,7] and 57–73% amongst physiotherapists [21,27,29].

Intuitively, the high prevalence reported by nurses and paramedics is not surprising given the biomechanical demands associated with patient handling. However, the high prevalence in professions such

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as dentistry and chiropractic have also reported relatively high incidence of LBP and other MSDs [6,14, 19,23] with arguably much lower occurrence of high exertion demands. Previous research investigating these professions propose that the poor sitting posture [19,26], workstation design [14], long periods of static trunk and neck flexion [16,23], excessive trunk twisting, unnatural static postures, high compressive and shearing forces on the spine [16] are major contributors to LBP and MSD development. The cumulative load on the spine has recently emerged as a potential mechanism and independent risk factor of LBP [10,24]. This idea, first considered by Kumar in 1990 [10], suggests that although peak compressive and shearing forces on the spine may appear to be within an acceptable range they may still put the back at risk dependent on length of exposure. Greater cumulative loads can be impacted by either higher repetitions or longer duration of a task [5]. Research has shown that increased frequency of patient handling is positively correlated with the developing back pain [7]. Prevalence of back pain in nurses who handled patients frequently was 37 times higher that those who only handled patients infrequently [8].

Until recently, few studies have focused on the biomechanical demands of health care practitioners, such as dentists, chiropractors or massage therapists, who do not have patient-handling as a major job task. Recent work by Newell and Kumar [23] and Kumar and Narayan [11] highlighted the cumulative loading demands associated with static trunk and neck postures in orthodontists and x-ray technicians, respectively. Mior and Diakow [20] reported that 41% of chiropractors in their study felt the postural demands created by treatment techniques and patient positioning were key factors in their development of back pain. Mior indicated that further research is needed to investigate the risk of the normal working postures. Workstation height has been shown to affect chiropractors' sagittal flexion, disk compression force and ligament strain while performing lumbar, thoracic, and cervical manipulations [14]. Table heights below 465 mm put the most strain on the back as it required more flexion of the back and greater force to perform the manipulation. Chiropractors perform all of their spinal manipulations while the patient is lying on a table and spend little time with each client. A massage therapy treatment on the other hand typically last between 30 minutes and one hour. Therefore, the massage therapist is at a higher risk of cumulative exposure to the low back and upper extremity if they are required to maintain awkward static postures for a significant time period.

To the authors' knowledge a biomechanical analysis of Massage Therapists has not been conducted and this lack of research presents a void in the work-related demands of a growing healthcare profession. Therefore the purpose of this study was to determine the biomechanical demands on the low back of massage therapists performing typical massage therapy techniques.

2. Methods

2.1. Participants

Participants consisted of eight females (27 $\pm$ 3.5 yrs; 58.2 $\pm$ 10.9 kg; 1.6 $\pm$ 0.5 m) and two males (25 $\pm$ 1.4 years; 81.5 $\pm$ 1.4 kg; 1.8 $\pm$ 0.3 m) recruited from the Atlantic College of Therapeutic Massage (ACTM, Fredericton, New Brunswick, Canada). Although an even proportion of male and females Massage therapists was desired, the proportion in this study is reflective of that present in the profession. For example, the American Massage Therapy Association current membership is predominately female at 84% [1]. Inclusion in the study was restricted to registered massage therapists or students in their second and final year of study, to insure that they were familiar and well practiced in the traditional techniques assessed in this study. All participants were presented with a letter outlining the study and

Table 1
Participant demographics

Subject	Gender	age (yrs)	weight (kg)	height (cm)	table ht (cm)	table ht (% of standing ht)
MT1	F	27	61.4	164.0	69.0	42.1
MT2	F	31	58.0	161.5	70.0	43.3
MT3	F	23	47.1	160.0	64.0	40.0
MT4	F	26	45.8	162.0	69.0	42.6
MT5	F	27	56.3	168.5	71.0	42.1
MT6	F	33	80.5	173.5	74.0	42.7
MT7	F	26	53.6	165.0	69.0	41.8
MT8	F	23	63.2	166.0	69.0	41.6
MT9	M	24	82.5	178.0	79.0	44.4
MT10	M	26	80.5	182.0	75.0	41.2
Group average		27	62.9	168.1	70.9	42.2
SD		3	13.8	7.4	4.1	1.2
females		27	58.2	165.1	69.4	42.0
SD		4	10.9	4.4	2.8	1.0
Males		25	81.5	180.0	77.0	42.8
SD		1	1.4	2.8	2.8	2.2

provided an opportunity to ask questions of the researchers before signing a form of consent approved by the ethics committee at the University of New Brunswick. Standard anthropometrics data was then collected (height, weight, table height used) prior to testing (Table 1).

2.2. Procedure

Each massage therapist performed a standardized 44-minute general relaxation back massage that included basic techniques used by the therapists. A prerecorded audiotape provided instruction to the massage therapist, indicating the technique to use, the area of the body to concentrate the massage on and length of time to perform the technique. The instructions would inform the therapists when a change in technique was coming in advance to allow for proper transition. The standardized routine is outlined in Table 2 and a diagram of the corresponding body regions, which was posted on the wall next to the therapist, is provided as Fig. 1. Each therapist chose a table height they felt appropriate for them and the client they were working with. All clients (individuals receiving the massage) were students from the Faculty of Kinesiology.

The massage was captured at 30 frames/s by two standard video cameras, placed at oblique viewing angles on either side of the massage table in order to provide a clear view of the therapist at all times. The cameras were left running for the duration of the massage. Once the massage was completed the applied force was measured while the therapists replicated each technique. A towel, attached to a Chantillion DM-100 force gauge (AMETEK Inc., Paoli, PA, USA), was placed over the client's back. The therapist was then asked to perform each of the techniques on the client with the same force used during the massage session. These hand forces were used as input to a 3D static biomechanical model to determine low back loads.

2.3. Data analysis

For analysis purposes, a complete cycle of video for each of the 13 different massage techniques was captured to a computer and down sampled to a frame rate of 5 frames/s [4,10,11]. Postural assessments and joint mechanics were accomplished using 3DMatch [4,5]. Body postures were selected from a

Table 2
Outline of the 44-minute general relaxation back massage. The length of time spent performing each technique is provided in the left column. A brief definition of each technique is provided in the Appendix

General Techniques	
1 minute	Static contact over sheet
1 minute	Stroking over sheet & drape
5 minutes	Light effleurage entire back
2 minutes	Wringing – entire back (approx. 3x's)
Specific Technique	
5 minutes	Quadrant 1 – wringing, picking up (c-kneading), effleurage
2 minutes	Quadrant 1–2 – picking up (c-kneading), effleurage
5 minutes	Quadrant 3 – wringing, picking up (c-kneading), effleurage
2 minutes	Quadrant 3, 4 – picking up (c-kneading), effleurage
3 minutes	Quadrant 3,4 – deep effleurage 2 x's fingers and 3x's with forearms
2 minutes	Quadrant 3,4 – muscle stripping with forearm
2 minutes	Quadrant 3,4 – light effleurage
3 minutes	Quadrant 1, 2 - deep effleurage 2x's fingers and 3x's with forearms
2 minutes	Quadrant 1,2 – muscle strippings with forearms
2 minutes	Quadrant 1,2 – light effleurage
1.5 minutes	Quadrant 4 – palmar knead, light effleurage, compressions to quadrants 2,1,3,4 as a transition
1.5 minutes	Quadrant 2 – palmar kneads, light effleurage
General Techniques	
2 minutes	Wringing entire back
1 minute	Stroking over sheet & drape
1 minute	Static contact

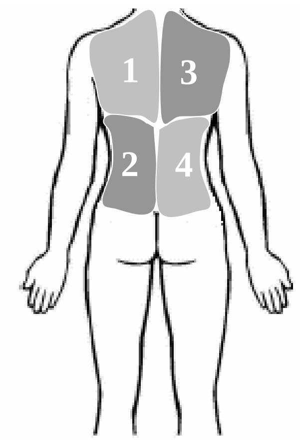

Fig. 1. Body quadrant diagram provided to the therapists as they performed the 44-minute massages outlined in Table 2.

series of posture bins presented to the user. Trunk flexion was represented by six posture bins from -30 to 130 degrees. The frontal and transverse planes of the trunk motion were each represented by six bins. Similar bin selections are conducted for the neck flexion (four bins), neck lateral bend (four bins), flexion/extension of the right and left elbow (three bins), and flexion/extension (six bins) and abduction of the right and left shoulder (four bins). The selected postures are used as input to a 3D rigid link static model to determine reaction forces and moments at L4/L5. Single muscle equivalent and a third order polynomial joints models [18] were used to calculate joint or bone-on bone forces [4]. Cumulative loads were determined by integrating the L4/L5 moments and forces over the time to complete the tasks [4]. Daily cumulative loads were estimated based on four and five massages a day and did not account for

Table 3
Percent time spent in neutral, mild and severe trunk, shoulder and neck postures during the 44-minute massage, separate by massage technique

Technique	Trunk flexion posture			Arm/shoulder flexion						Neck flexion posture		
	neutral (< 20°)	mild (20° to 45°)	severe (> 45°)	neutral (< 20°) left	neutral (< 20°) right	mild (20° to 90°) left	mild (20° to 90°) right	severe (> 90°) left	severe (> 90°) right	neutral (−10° to 10°)	mild (10° to 30°)	hyper extension (−60° to −10°)
Effleurage to a lower quadrant	73.9	26.1	0.0	44.9	44.2	55.1	55.8	0.0	0.0	32.5	67.5	0.0
Effleurage to an upper quadrant	51.1	48.9	0.0	40.1	43.7	59.9	56.3	0.0	0.0	57.8	39.4	0.3
Effleurage to one side	50.8	49.2	0.0	20.7	33.6	79.3	66.4	0.0	0.0	56.4	49.9	0.6
Effleurage to the entire back	36.2	59.0	4.4	11.3	21.0	88.7	79.0	0.0	0.0	31.4	68.6	0.0
Deep effleurage	45.5	54.5	0.0	10.1	11.3	89.9	88.7	0.0	0.0	60.2	39.8	0.0
Muscle Stripping	0.0	92.3	7.7	9.3	21.4	90.7	78.6	0.0	0.0	61.5	38.5	0.0
Palmer kneads	42.9	55.0	2.0	49.2	33.3	50.7	66.7	0.0	0.0	59.7	39.1	0.9
“c”-kneads to one quadrant	28.2	86.1	8.0	27.5	28.2	72.5	71.8	0.0	0.0	28.6	71.4	0.0
“c”-kneads to one side	50.0	50.0	0.0	42.6	36.2	57.4	63.8	0.0	0.0	50.8	49.2	0.0
Stroking	74.2	25.8	0.0	40.8	45.0	54.9	55.0	0.0	0.0	39.5	60.0	0.5
Static touch	100.0	0.0	0.0	26.3	36.1	73.7	63.9	0.0	0.0	0.0	100.0	0.0
Wringings to one quadrant	10.0	90.0	0.0	21.7	24.4	78.3	75.6	0.0	0.0	0.0	100.0	0.0
Wringings to one side	68.0	32.0	0.0	28.6	35.5	71.4	64.5	0.0	0.0	41.3	58.7	0.0
Mean	**48.5**	**51.4**	**1.7**	**28.7**	**31.8**	**71.0**	**68.2**	**0.0**	**0.0**	**40.0**	**60.2**	**0.2**
sd	**27.1**	**27.0**	**3.0**	**13.8**	**10.2**	**14.2**	**10.2**	**0.0**	**0.0**	**21.3**	**21.2**	**0.3**

any other activities (i.e. lunch or break times).

2.4. *Analysis*

A descriptive analysis was conducted to determine the percentage of massage time spent in neutral and non-neutral trunk, shoulder and neck postures. The severity of trunk, shoulder and neck postures was established from previous literature [17,22]. Table 3 outlines the posture ranges that defined neutral, moderate and severe for each posture segment. Descriptive statistics were calculated for the peak and cumulative lumbar and shoulder loads.

3. Results

3.1. *Posture*

The assessment of trunk, shoulder and neck postures was made in accordance to the postural bins established in the 3DMatch program. As outlined in Table 3, the Massage Therapists spent little time in postures categorized as severe. The effleurage to the entire back, muscle stripping and “c” kneads required severe posture of the trunk for less than 10% of the activity time. On average, during 50% of the massage, the trunk was required to be flexed away from neutral into a mild posture. Deviations from neutral to mild postures were also required of the arms and shoulders as well as the neck for 70% and 60% of the massage, respectively. Again muscle stripping and effleurage required the largest percentages of time in non-neutral postures. This is significant in that the largest time was spent performing effleurage techniques. Activities such as static touch and wringings required the largest percentage of time in non-neutral neck postures, but fortunately these techniques were performed for short durations (1 minute).

Table 4
Mean hand forces (N) measured for different massage techniques used in the biomechanical modeling

Subject	Light Effleurage	Deep Effleurage	Muscle Stripping	C-Scoop	Wringing	Mean	SD
MT1	5.9	14.2	10.3	11.8	9.3	10.3	3.1
MT2	2.5	9.3	7.8	11.3	7.4	7.7	3.3
MT3	2.0	3.9	4.9	6.4	7.4	4.9	2.1
MT4	2.5	5.4	6.4	10.3	16.2	8.1	5.3
MT5	5.4	7.4	7.4	7.4	6.4	6.8	0.9
MT6	2.9	9.3	11.3	8.3	11.8	8.7	3.5
MT7	4.4	7.4	8.3	9.3	5.9	7.1	1.9
MT8	2.0	5.9	4.4	7.4	10.3	6.0	3.1
MT9	11.3	14.7	7.8	24.0	15.2	14.6	6.0
MT10	2.5	5.4	8.7	7.8	9.8	6.8	2.9
Mean	4.1	8.3	7.7	10.4	10.0		
SD	2.9	3.7	2.1	5.1	3.5		

Table 5
Peak lumbar loads (compression and shear) at the L4/L5 level for each massage technique

	Compression (N)		Joint Anterior Shear (N)		Joint Posterior Shear (N)	
	mean	sd	mean	sd	mean	sd
Effleurage to Lower Quadrant	1586.0	604.3	−58.1	45.4	24.7	21.7
Effleurage to Upper Quadrant	1556.9	570.6	−58.1	45.4	24.7	21.7
Effleurage to One Side	1547.2	557.7	−71.6	42.5	26.9	21.7
Effleurage to Entire Back	1586.0	604.3	−78.2	43.4	54.6	94.1
Deep Effleurage	1477.2	350.8	−65.2	41.6	27.4	10.0
Muscle Stripping	1713.9	567.3	−78.0	31.7	0.0	0.0
“c”-kneads to one quadrant	1585.3	317.5	−55.6	30.1	23.6	15.8
“c”-kneads to one side	1392.8	374.4	−37.6	41.7	14.9	17.3
stroking	1173.5	74.4	−20.5	32.3	23.0	19.8
static touching	1264.5	261.3	0.0	0.0	15.9	4.9
wringings to one quadrant	1633.4	449.6	−76.6	51.4	12.7	20.0
wrinings to entire back	1336.2	161.0	−53.0	47.0	19.4	9.8
average	1487.7	407.8	−54.4	37.7	22.3	21.4
sd	162.4	180.8	24.2	13.6	12.8	24.0

3.2. *Peak and cumulative loading*

The measured hand forces and peak trunk loads are outlined for each technique in Tables 4 and 5, respectively. The average peak trunk compression across all techniques was approximately 1490 N with the muscle stripping and wringing techniques generating the highest peak compressions ($>$ 1600 N). The average joint anterior and posterior lumbar shear across all techniques was 54 and 22 N, respectively. Effleurage technique generated the highest trunk shear ($>$ 70 N of joint anterior shear).

The cumulative trunk loads for each subject are reported in Table 6. The average cumulative trunk compression for the 44-minute massage ranged from 2.8 to 4.6 MN·s, with an average around 3.5 MN·s. The effleurage technique, being the most commonly used technique, was responsible for the highest cumulative loading during the massage. Lumbar joint anterior shear ranged from 26,000 N·s to 170,000 N·s for the ten massage therapists.

Table 6
Average cumulative load (N.s.) for each massage therapists for the 44-minute massage. Daily and weekly exposures were calculated based on either four or five massages/day. This daily exposure accounts for the time performing massages only

	Total Compression	Total J.A. Shear	Total J.P. Shear	Total R.A. Shear
MT1	3,354,470.07	−97,854.18	13,810.72	−250,479.35
MT2	3,171,623.79	−84,233.76	23,377.90	−200,845.44
MT3	2,897,258.93	−26,153.49	33,588.03	−60,605.05
MT4	4,634,783.14	−169,623.13	14,761.99	−370,777.41
MT5	3,355,306.24	−99,655.67	13,646.41	−270,243.23
MT6	2,964,617.23	−83,600.08	27,203.99	−209,149.55
MT7	3,103,344.65	−133,581.23	8,635.09	−281,366.91
MT8	3,667,597.25	−80,476.92	69,785.05	−223,927.50
MT9	4,634,783.14	−169,623.13	14,761.99	−370,777.41
MT10	3,764,074.29	−135,509.20	12,760.44	−390,365.60
Mean	3,581,620.47	−117,074.37	24,465.50	−290,971.70
stdev	601,746.11	35,034.28	23,065.92	74,779.42
daily exposure[1]	17,908,102.34	−585,371.86	122,327.48	−1,454,858.50
daily exposure[2]	14,326,481.87	−468,297.49	97,861.98	−1,163,886.80
weekly exposure[1]	89,540,511.70	−2,926,859.32	611,637.39	−7,274,292.48
weekly exposure[2]	71,632,409.36	−2,341,487.46	489,309.91	−5,819,433.98

[1]Based on 5 massages/day and a five day work week.
[2]Based on four massages/day and a five day work week.

4. Discussion

4.1. The workstation and therapists' posture

Ergonomically, the massage therapist has an uncomplicated work environment. The massage techniques investigated in this study were performed on clients who were lying prone on the massage table with the entire massage being performed from a standing posture. Therefore, the massage table is significant in dictating the body postures used by the therapists. Improper work station design can lead to poor postures and body mechanics resulting in increased musculoskeletal injuries. Ideally, the correct table height would vary depending on the technique being used. This is, however, not the reality. The therapist typically sets the table height based on the size of the client at the start of the massage treatment and this is impractical to change once a client is positioned on the table. Training manuals instruct a proper working height of a table to be between the height of the therapist's wrist and the tips of the extended fingers. But they suggest that occasionally the optimum height may be as low as the therapist's knees to as high as their waist [2]. An investigation into ideal table heights for chiropractic adjustments suggested that a medium table (∼655 mm) height setting was ideal for reducing back strain for the chiropractor during thoracic and lumbar adjustments, but that a higher table height (∼845 mm) would be better when performing cervical adjustments. These table heights represent the 85%ile finger tip height for females and 50th%ile for males, respectively [9]. Anthropometric tables for North American males and females indicate that the average fingertip height is 38% of stature. Interestingly, the massage therapists, in this study, all chose tables heights that were 40–43% of their standing height which would be between their fingertips and wrists, as suggested in their training manuals.

The trunk, shoulder and neck postures required of the Massage Therapists ranged depending on the task. On average, the trunk posture was divided 50:50 between the neutral and mild posture categories, while the shoulder and neck were in neutral postures for 30 and 40 percent of the time, respectively.

The largest period of time was spent performing the effleurage technique and it required the trunk to assume a mild trunk posture 60% of the time, mild shoulder postures nearly 90% of the time and a mild neck posture for approximately 70% of the time. Muscle stripping was a demanding technique as the trunk was never engaged in the neutral position and was in a severe position for approximately 8% of the time. This technique also required the shoulder to assume a mild posture for a majority of the time. Fortunately, in this massage treatment the technique was only used for 5 minutes which may not be the case in all treatments. Similar results were seen for the ‘c’-kneads but again it was performed for a total of three minutes. Overall, the therapists were in neutral postures less than 50% of the time but on a positive note the trunk, shoulder and neck were placed in a severe posture minimally during the treatment.

Punnett et al. [25] found that the risk of back disorders increased significantly with time worked in non-neutral postures and that the risk increased further when a non-neutral posture was used in more than one of the principal axes at a time. They found that a mild trunk flexion of greater than 10% of the cycle time resulted in odds ratio of 6.1 and assuming a severe trunk flexion for as little as 10% of the cycle time produced an odds ratio of 4.4 and jumped to 8.9 for periods exceeding 10% of the cycle time. Given that the posture categories reported in this study mirrored those of Punnett et al.’s work, the significant working time in a mild trunk flexion reported for the Massage Therapists is reason for concern.

The static nature of the flexed positions of the neck, shoulder, elbow and trunk has been shown to be a primary concern with orthodontists [23]. The authors provide a description of the task to be a seated activity requiring a trunk angle between 0° and 25°, shoulders abducted between 0° and 90° and neck flexed between 50° and 95°. Both the trunk and shoulder postures would correspond to our mild category and their neck posture would be considered severe. Therefore, it is of little surprise that the dentistry profession has reported a significant prevalence of neck pain [23].

4.2. Peak and cumulative loads

The peak trunk compression and shear values are relatively low if compared to published risk threshold levels of 3400 N for compression [31] and 500 N for shear [24,32]. This result is not surprising given the low hand forces. However, the trunk postures required of the therapists lead to significant cumulative loads of 3.5 MN for a 44-minute massage. When extrapolated for an average of five massages for a given work day the cumulative trunk compression loads are comparable to those reported for orthodontists [23]. The higher cumulative compression reported in this study may be attributed to the addition of hand forces into the calculation, a parameter absent in the Newell and Kumar [23] study or the use of a 3D joint model [18]. The relatively neutral trunk position adopted during the massage resulted in small cumulative anterior and posterior shear. This is in contrast to the orthodontists, who were reported to work with a severe trunk flexion [23] and as a result reported shear values that were 10 times greater than reported in this study.

4.3. Limitations

One of the difficulties in assessing the demands of the massage was the recording of hand forces. The use of instrumented gloves or a force pad would have greatly altered the therapist’s performance. As such, we were limited to obtaining the average force for each technique, which likely resulted in an underestimation of the cumulative load calculations [11]. The massages were structured and reflect standard techniques (as described in Andrade and Clifford [2]) but it is understood that the severity of the muscular problems, the physical size of the client, the experience of the therapist and the area would dictate the time spent using a specific technique and the amount of force used. All of these factors would impact the estimation of the cumulative loading but this study has provided a conservative estimate of the demands on the massage therapists.

5. Conclusions

This biomechanical assessment of typical massage therapy techniques revealed peak lumbar compression and shear loading that would be considered ‘safe’ by current guidelines. The associated daily cumulative exposure, however, produced levels that have been reported in other health care professions and manufacturing work to place the workers at risk of musculoskeltal disorders. Of equal concern is the percentage of time the therapists spent in non-neutral postures. Given the low relative hand loads associated with massage techniques it is important that Massage Therapists are educated on personal back health including the use of proper technique that involves neutral trunk and shoulder postures to reduce the cumulative exposure to the low back and shoulders. In summary, the conclusions reached from this investigation are that:

– on average, the massage therapists’ employed a non-neutral trunk, arms and shoulder postures 50%, 70% and 60% of the massage treatment.
– the average peak trunk compression across all techniques was approximately 1500 N with the average joint anterior and posterior lumbar shear being less than 50 N
– the average cumulative trunk compressions for one massage treatment was 3.5 MN·s
– a four massage/day, five day/week work routing would result in a daily cumulative trunk exposure of 14 MN·s and a weekly trunk exposure of 71 MN·s

References

[1] American Massage Therapy Association. (2005). *AMTA Member Demographics*. Retrieved November 2005, http://www.amtamassage.org/pdf/AMTAdemographics03.pdf
[2] C.K Andrade and P. Clifford, *Outcome-Based Massage*, Lippincott Williams & Wilkins, 2000.
[3] P. Buckle, The handling of patients – A guide for nurses, *International Journal of Nursing Studies* **24**(4) (1987), 348–349.
[4] J.P. Callaghan, Cumulative spine loading: From basic science to application, in: *The Occupational Ergonomics Handbook 2nd Ed.: Fundamentals and Assessment Tools for Occupational Ergonomics*, W. Karwowski and W.S. Marras, CRC Press, 2006, in press.
[5] M.P. deLooze, E. Zinzen, D. Caboor, P. Heyblom, E. vanBree, P. vanRoy, H.M. Toussaint and J.P. Clarijs, Effect of individually chosen bed-height adjustments on the low-back stress of nurses, *Scandinvavian Journal of Work Environment Health* **20** (1999), 427–434.
[6] P.R.P. Diakow and J.D. Cassidy, Back pain in dentists, *Journal of Manipulative and Physiological Therapeutics* **7**(2) (1984), 85–88.
[7] S. Hignett, Work-related back pain in nurses, *Journal of Advanced Nursing* **23** (1996), 1238–1246.
[8] R.C. Jensen, Back injuries among nursing personnel related to exposure, *Applied Occupational and Environmental Hygiene* **5**(1) (1990), 38–45.
[9] K. Kroemer, H. Kroemer and K. Kroemer-Elbert, *Ergonomics. How to Design for Ease and Efficiency*, Prentice-Hall, 2001, 15–50.
[10] S. Kumar, Cumulative load as a risk factor, *Spine* **15** (1990), 1311–1316.
[11] S. Kumar and Y. Narayan, Cumulative spinal load among X-ray technologist: A field study of techniques, frame rate and prediction, *International Journal of Industrial Ergonomics* **35** (2005), 889–903.
[12] W.M. Kyserling, M. Brouwer and B.A. Silverstein, A checklist for evaluating ergonomic risk resulting from akward postures of legs, trunk and neck, *International Journal of Industrial Ergonomics* **9** (1992), 283–301.

[13] S.A. Lavender, K. Conrad, P.A. Reichelt, P.W. Johnson and F.T. Myer, Biomechanical analyses of paramedics simulating frequently performed strenuous work tasks, *Applied Ergonomics* **31** (2000), 167–177.
[14] K.J. Lorme and S.A. Naqvi, Comparative analysis of low-back loading on chiropractors using various workstation table heights and performing various tasks, *Journal of Manipulative and Physiological Therapeutics* **26**(1) (2003), 25–33.
[15] W.S. Marras, K.G. Davis, B.C. Kirking and P.K. Bertsche, A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques, *Ergonomics* **42**(7) (1999), 904–926.
[16] W.S. Marras, S.A. Lavender, S.E. Leurgans, F.A. Fathallah, S.A. Ferguson, W.G. Allread and S.L. Rajulu, Biomechanical risk factors for occupationally related low back disorders, *Ergonomics* **32** (1995), 377–410.
[17] L. McAtammey and E.N. Corlett, Ergonomic workplace assessment in a health care context, *Ergonomics* **35**(9) (1992), 965–978.
[18] S.M. McGill, R.W. Norman and J. Cholewicki, A simple polynomial that predicts low-back compression during complex 3-D tasks, *Ergonomics* **39** (1996), 1107–1118.
[19] C. Michalak-Turcotte, Controlling dental hygiene work-related musculoaskeletal disorders: The ergonomic process, *Journal of Dental Hygiene* **74**(1) (2000), 41–48.
[20] S.A. Mior and P.R.P. Diakow, Prevalence of back pain in chiropractors, *Journal of Manipulative and Physiological Therapeutics* **10**(6) (1987), 305–309.
[21] M. Molumphy, B. Unger, G.M. Jensen and R.B. Lopopolo, Incidence of work-related low-back pain in physical-therapists, *Physical Therapy* **65**(4) (1985), 482–486.
[22] P. Neumann, R.P. Wells, R.W. Norman, J.W. Frank, H.S. Shannon and J.R. Kettering, A posture and load sampling approach to determining low-back pain risk in occupational settings, *International Journal of Industrial Ergonomics* **28** (2001), 355–365.
[23] T.M. Newell and S. Kumar, Comparison of instantaneous and cumulative loads on the low back and neck in orthodontists, *Clinical Biomechanics* **20** (2005), 130–137.
[24] R.W. Norman, R.P. Wells, J.W. Frank, H.S. Shannon and M. Kerr, and the Ontario Universities Back Pain Study (OUBPS) Group, A comparison of peak vs cumulative physical work exposure risk factors for the reporting of low back pain in the automotive industry, *Clinical Biomechanics* **13** (1998), 561–573.
[25] L. Punnett, L.J. Fine, M. Keyserling, G.D. Herrin and D.B. Chaffin, Back disorders and nonneutral trunk postures of automobile assembly workers, *Scan J Work Environ Health* **17** (1991), 337–346.
[26] L.M. Rucker and S. Sunell, Ergonomic risk factors associated with cinical dentistry, *California Dental Assiociation Journal* **30**(2) (2002), 139–148.
[27] D. Rugeli, Low back pain and other work-related musculoskeletal problems among physiotherapists, *Applied Ergonomics* **34** (2003), 635–639.
[28] B. Schibye, F. Hansen, C.T. Hye-Knudsen, M. Essendrop, M. Böcher and J. Skotte, Biomechanical analysis of the effect of changing patient-handling technique, *Applied Ergonomics* **34** (2003), 115–123.
[29] M. Scholey and M. Hair, Back pain in physiotherapists involved in back care education, *Ergonomics* **32**(2) (1989), 179–190.
[30] J. Skotte, M. Essendrop, A.F. Hansen and B. Schibye, A dynamic 3D biomechanical evaluation of the load on the low back duirng different patient-handling tasks, *Journal of Biomechanics* **35** (2002), 1357–1366.
[31] Waters et al.
[32] V.R. Yingling and S.M. McGill, Mechanical properties and failure mechanics of the spine under posterior shear load: observations from a porcine model, *J Spinal Disorders* **12**(6) (1999), 501–508.

Appendix

A brief description of the massage techniques used in this study as defined by Andrade and Clifford (2001).

Compressions: A force oriented in a manner to shorten or compact a tissue.

Effleurage: A group of general guiding manipulations performed with centripetal pressure and varying pressures.

(**Palmar**) **Kneading:** A gliding neuromuscular technique, performed in circles or ellipses, which repeatedly compresses and releases muscle.

Muscle Stripping: A slow, specific, gliding neuromuscular technique that is applied from the origin of the muscle to its insertion for the purpose of reducing the activity of trigger points.

Static Contact: A superficial reflex technique in which the clinician's hands contact the client's body without motion and with minimal force.

Wringings: A petrissage technique in which muscle is lifted and sheared between contact surfaces that are moving in opposite directions.