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ORIGINAL RESEARCH

Systematic Review of Contracture Reduction in the Lower Extremity with Dynamic Splinting

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ABSTRACT

Introduction: Joint contractures are relatively common disorders that can result in significant, long-term morbidity. Initial treatment is non-operative and often entails the use of mechanical modalities such as dynamic and static splints. Although widely utilized, there is a paucity of data that support the use of such measures. The purpose of this systematic review was to evaluate the safety and efficacy of dynamic splinting as it is used to treat joint contracture in lower extremities, and to determine if duration on total hours of stretching had an effect on outcomes.

Methods: Reviews of PubMed, Science Direct, Medline, AMED, and EMBASE websites were conducted to identify the term 'contracture reduction' in manuscripts published from January 2002 to January 2012. Publications selected for inclusion were controlled trials, cohort studies, or case series studies employing prolonged, passive stretching for lower extremity contracture reduction. A total of 354 abstracts were screened and eight studies (487 subjects) met the inclusion criteria. The primary outcome measure was change in active range of motion (AROM).

Results: The mean aggregate change in AROM was 23.5° in the eight studies examined. Dynamic splinting with prolonged, passive stretching as home therapy treatment showed a significant direct, linear correlation between

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the total number of hours in stretching and restored AROM. No adverse events were reported.

Discussion: Dynamic splinting is a safe and efficacious treatment for lower extremity joint contractures. Joint specific stretching protocols accomplished greater durations of end-range stretching which may be considered to be responsible for connective tissue elongation.

Keywords: Connective tissue; Dynasplint; Home therapy; Orthopedics; Rehabilitation

INTRODUCTION

Contracture is the molecular shortening of connective tissue [1–5]. Contracture includes realignment of the elastin polypeptide "bridges" across the longitudinal collagen trihedral scaffolds causing what previously was considered a "permanent shortening". Contracture occurs following prolonged joint positioning (immobilization), excessive arthrofibrosis (common following surgical procedures), idiopathic, neural hypertonicity, and due to obstruction [1–23].

Contracture is clinically different from ankylosis in that contracture is an exclusively soft tissue anomaly, whereas ankylosis is an adhesion between arthritic structures. Treatment for contracture reduction has included surgical manipulations [6, 7], sequential, serial casting [8, 9], and passive stretching [10–23]. There has been a long debate on splinting modalities of static splinting versus dynamic splinting with sequential tension changes in combination with other protocols [10–37]. Current literature has shown dynamic splinting with prolonged passive stretching to be an effective, safe modality [11–22, 33–36].

A study completed by Usuba et al. [23] examined the effect of "low torque, long duration" stretching on contracture. The contracture was induced with surgical immobilization of 66 rat knees and extension was set at 150° of flexion for 40 days. After remobilization with removal of the hardware, the mean flexion contracture was −125° (125° from full extension). The increased contracture could be attributed to excessive arthrofibrosis; decreased afferent sensitivity has also been a proposed factor in contracture development [6, 7, 10, 24]. Rats were randomly assigned to one of six treatment groups: control, surgical remobilization, stretching with high torque and short duration, stretching with high torque and long duration, stretching with low torque and short duration, and stretching with low torque and prolonged duration. Twelve treatments of stretching occurred over a 4-week period and all measurements were done by one person. All treatment groups in this study showed a significant change in maximal extension under anesthesia. The only statistically significant difference between treatment protocols was for the group that used low torque, long duration repeated stretching [23]. It is hypothesized that altered reflex sensitivity may also be involved in explaining why prolonged durations of passive stretching are successful in contracture reduction [10].

A comprehensive program including prolonged passive stretching is recommended following a TKA [6, 17, 18, 25, 26]. Deficits in extension have remained following traditional therapies delivered after total knee arthroplasty (TKA) [25] but studies employing prolonged passive stretching have restored knee extension deficits following the TKA [17, 18]. The low torque, prolonged duration stretching modality was used as the standard of care for chronic extension deficits of the knee in a study of 121 patients by Freiling and Lobenhoffer [6]. They combined surgical resolution with dynamic splinting immediately following the procedure.

The purpose of this systematic review was to evaluate the safety and efficacy of dynamic splinting which delivers low torque, prolonged duration of stretching to treat joint contracture in the lower extremities (LE), and to determine if duration on total hours of stretching had an effect on outcomes.

METHODS

Reviews of PubMed, Science Direct, Medline, AMED, and EMBASE websites were conducted to identify the term ‘contracture reduction’ in manuscripts published from January 2002 to January 2012. Publications selected for inclusion were controlled trials, cohort studies, or case series studies employing prolonged, passive stretching for LE contracture reduction. A total of 354 abstracts were screened and eight studies (487 subjects) met the inclusion criteria. The primary outcome measure was a change in maximal active range of motion (AROM).

Data Analysis

Software used in this data analysis was SPSS. (SPSS Inc., Chicago, IL, USA). Outcome measures of these studies examined change in AROM as a common, dependent variable (Table 1) [6, 11, 15–17, 23]. Since the duration (in weeks), LE (sample size N) and total hours stretching varied in the clinical trials, it was decided to analyze using three weighted dependent variables, namely, (1) duration-weighted AROM $= W_1$ AROM, (2) study size-weighted AROM $= W_2$ AROM, and (3) hours-weighted AROM $= W_3$ AROM where the weights (for cases) were calculated as $W_1 =$ duration/sum of all durations, $W_2 = N$/sum of all N, and $W_3 =$ total hours stretching/sum of all total hours stretching as shown in Tables 1, 2, 3, and 4.

The analysis in this article is based on previously conducted studies and does not involve any new studies of human or animal subjects performed by any of the authors.

RESULTS

Of the eight studies included, four assessed the knee, three involved toes and two evaluated ankles (Table 1). The studies ranged from 3 to 25 weeks, with the majority studying prolonged stretching under low tension. Total hours of stretching ranged from 4 to 1,260 h. One study, Usuba et al. [23], involved a preclinical model.

With the three weighted variables, only the W_1 AROM and W_3 AROM variables were significantly correlated with $r_{13} = 0.88$ and p value of 0.002. The correlations among the other variables were insignificant. This suggests that there was an outlier in each weighted dependent variable. The median value of (1) was largest, followed by (2) and (3) in a hierarchical manner. Table 2 attests that the mean of the hours-weighted AROM was significant, while the means of the duration-weighted AROM and the size-weighted AROM were insignificant at 0.05 significance level.

The hours-weighted AROM was significantly different from the size-weighted AROM and duration-weighted AROM at 0.05 level of significance. Finally, a principal component analysis revealed that the variables “tension” and “stretching” had closer proximity than the variable “joint” in the results of these principle studies. Likewise, another principal component analysis revealed that the variables “duration-weighted AROM” and “hours-weighted

Table 1 Clinical trials data

1st Author	Ref.	Joint	Stretching	Tension	Weeks	*N*	Total hour stretching	Change AROM	*P* value	*W1*	*W2*	*W3*	*W1* AROM	*W2* AROM	*W3* AROM
Lai	[13]	Ankle	Long	Low	25	50	1260	31	0.007	0.338	0.103	0.4134	10.47	3.18	12.81
John	[11]	Toe	Long	Low	8	48	218	28	0.0001	0.108	0.099	0.0715	3.03	2.76	2
Armstrong	[17]	Knee	Long	Low	3	107	200	7.8	0.0001	0.041	0.22	0.0656	0.32	1.71	0.51
Usuba	[23]	Knee	Long	Both	4	17	8	77.8	0.0001	0.054	0.035	0.0026	4.21	2.72	0.2
			Short	Both	4	17	4	68.4	0.0001	0.054	0.035	0.0013	3.7	2.39	0.09
Curran	[16]	Ankle	Long	Low	16	18	784	23.4	0.0001	0.216	0.037	0.2572	5.06	0.86	6.02
Lopez	[19]	Ankle	Long	Low	5	48	241	9.4	0.0001	0.0068	0.099	0.0791	0.64	0.93	0.74
Freiling	[5]	Knee	Long	Low	5	121	245	17		0.068	0.249	0.0804	1.15	4.22	1.37
Kalish	[15]	Toe	Long	Low	4	61	88	16.3	0.001	0.054	0.125	0.0289	0.88	2.04	0.47

AROM active range of motion, *LE* lower extremity

AROM" had closer proximity than the "size-weighted AROM" in the results of these principal authors.

Efficacy was proven in the trials examined and a change in AROM in these studies ranged from 7° to 31°, excluding the animal study which showed maximal improvement up to 78° (Table 1). The mean aggregate change in AROM was 23.5°. The weighted hours in meta-analysis showed significant difference within the analysis, and normal distribution. Both human and animal studies revealed a greater difference and improvement with prolonged passive stretching versus short durations of stretching. There was also consistency between studies of prolonged passive stretching in subjects with outcome in change of AROM ($N = 487$, ΔAROM = 23.5°, SD = 7.6).

Dynamic splinting for contracture reduction showed a direct, linear correlation between the total number of hours in stretching and restored AROM. Contracture reduction of the LE that included dynamic splinting in the initial, non-operative treatment obtained the greatest hours of prolonged, passive, biomechanically appropriate, end-range stretching for the greatest change in AROM.

There were no adverse events reported in the studies examined.

DISCUSSION

Therapeutic considerations in treatment of contractures often include safety, efficacy, availability, cost, and time. No adverse events were reported and this is attributed to the fact that dynamic splinting is non-invasive, with daily application by the patient or family caregiver [6, 11–22, 33–35]. With other therapeutic measures such as serial casting, a 10% rate of adverse events would be expected, for example, due to skin breakdown.

Table 2 Estimates: dependent variable: compare–with variable

Weighted AROM	Mean	Std. error	95% Confidence interval	
			Lower bound	Upper bound
Hours-weighted AROM	3.628	0.750	1.792	5.464
Size (*N*)-weighted AROM	−0.514	0.750	−2.350	1.322
Duration-weighted AROM	0.950	0.750	−0.886	2.786

Table 3 Meta-analysis and 95% confidence interval

Dependent variable	Compare	With	Mean difference	95% CI lower	Upper
Hours-weighted AROM	Low tension	High tension	3.27	−0.95	7.5
	Long stretch	Short stretch	2.92	−8.07	13.02
	Joint ankle	Joint toe	5.28	−8.91	18.48
	Joint ankle	Joint knee	5.98	−8.91	20.87
	Joint toe	Joint knee	0.69	−5.48	6.87
Size-weighted AROM	Joint toe	Joint knee	−0.35	−2.15	1.43
	Joint ankle	Joint knee	−1.1	−3.73	1.52
	Joint ankle	Joint toe	−0.74	−3.58	2.1
	Long stretch	Short stretch	−0.08	−2.96	2.79
	Low tension	High tension	−0.3	−1.47	0.85
Duration-weighted AROM	Low tension	High tension	−0.87	−4.27	2.52
	Long stretch	Short stretch	−0.47	−9.05	8.09
	Joint toe	Joint knee	−0.38	−5.31	4.54
	Joint ankle	Joint knee	3.04	−7.82	13.92
	Joint ankle	Joint toe	3.43	−7.4	14.27

Efficacy was proven in the clinical trials examined with improvements in AROM ranging from 7° to 31°. Dynamic splinting has also shown efficacy in substantially reducing pain in randomized, controlled trials for plantar fasciopathy [12] and carpal tunnel syndrome [34]. Dynamic splinting is prescribed as a treatment of adhesive capsulitis with physical therapy because it achieves greater, total durations of joint specific stretching [35]. Doucet and Mettler [36] reported that dynamic splinting was also effective in an upper extremity study on wrist contracture reduction in stroke patients. Improved passive range of motion was observed in this 12-week study, but surprisingly the progress made diminished following discontinuation from treatment with dynamic splinting. This finding shows 'cause and effect' because the modality improved their ROM and tone management, but when discontinued, the stroke patients' contracture worsened.

The cost of dynamic splinting can be examined in dollars/hour, in comparison to manual therapy alone. Many dynamic splints rent for an average of $400 per month. The cost of treatment using a Dynasplint® (Dynasplint

Table 4 Pairwise comparisons: dependent variable: compare–with variable

(*I*) Weighted AROM	(*J*) Weighted AROM	Mean difference (I − J)	Std. error	Sig.[a]	95 % Confidence interval for difference	
					Lower bound	Upper bound
Hours-weighted AROM	Size-weighted AROM	4.142*	1.061	0.008	1.546	6.738
	Duration-weighted AROM	2.678*	1.061	0.045	0.082	5.274
Size-weighted AROM	Hours-weighted AROM	−4.142*	1.061	0.008	−6.738	−1.546
	Duration-weighted AROM	−1.464	1.061	0.217	−4.060	1.132
Duration-weighted AROM	Hours-weighted AROM	−2.678*	1.061	0.045	−5.274	−0.082
	Size-weighted AROM	1.464	1.061	0.217	−1.132	4.060

Based on estimated marginal means

* The mean difference is significant at the 0.05 level

[a] Adjustment for multiple comparisons: least significant difference (equivalent to no adjustments)

Systems, Inc, Maryland, USA) is approximately $2/hour of stretching ($400/240 h each month) and according to national scales, stretching in manual therapy costs $20 for a 15-min stretching session equaling $80/hour of stretching. Dynamic splinting is, therefore, much more cost-effective than stretching solely, accomplished at therapeutic clinics. The time dedicated to stretching with dynamic splinting is frequently accomplished at night while sleeping, therefore this has little effect on work or other therapeutic endeavors. Safety, efficacy, availability, cost, and time have positive outcomes with dynamic splinting [6, 11–23, 28, 33–36].

Wülker and Rudert [37] cautioned clinicians that contracture symptoms might be worsened if excessive "forceful attempt to restore a normal range of motion" is made. The protocol of low-load stretching with sequential tension changes in the dynamic splinting accomplishes that protection. Martin et al. [38] hypothesized that having a modality that is custom fit to the patient's foot size increases compliance in wear and the eventual outcome in contracture reduction. All of the human studies examined used custom fitting of the dynamic splinting devices [11, 13, 15–17, 19].

Regarding study limitations, the publications selected for review included both animal and human subjects, and the subjects were not equal in number. The treatment durations for different joints in the LE were different because of different joint specific stretching protocols (i.e., first metatarsal vs. knee). However, that difference was included in statistical analysis.

CONCLUSION

The intent of this systematic review was to evaluate the safety and efficacy of dynamic splinting which delivers low torque, prolonged duration stretching to treat joint contracture, and to determine if duration on total hours of stretching had an effect on outcomes. The mean aggregate change in AROM was 23.5° and a direct, linear statistical correlation was found between the total number of hours in stretching and restored range of motion.

Dynamic splinting is a safe and efficacious treatment for LE joint contractures. The joint specific, prolonged, passive stretching protocols accomplished greater durations of end-range stretching which may be considered responsible for the significant connective tissue elongations seen in the studies examined.

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Ethical standards. The analysis in this article is based on previously conducted studies, and does not involve any new studies of human or animal subjects performed by any of the authors.

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