The British Association of Plastic Surgeons (2003) **56**, 674–683

ELSEVIER

BJPS
An International Journal of Surgical Reconstruction
www.bjps.com

Do pre-operative abdominal exercises prevent post-operative donor site complications for women undergoing DIEP flap breast reconstruction? A two-centre, prospective randomised controlled trial☆

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Received 13 March 2003; accepted 8 July 2003

KEYWORDS
DIEP flap; Abdominal exercises; Muscle strength

Summary The deep inferior epigastric perforator (DIEP) flap is the gold standard for breast reconstruction using abdominal tissue. Unlike the transverse rectus abdominis myocutaneous (TRAM) flap, no rectus abdominis muscle is removed with the flap, but intra-muscular scarring can still cause post-operative complications. Strong abdominal muscles have been advocated as a prerequisite for surgery, but without any evidence as to the potential benefits. This study aimed to investigate the effect of pre-operative abdominal exercises on inpatient pain levels, length of hospital stay, post-operative abdominal muscle strength and function following a DIEP flap.

Ninety-three women undergoing delayed breast reconstruction with a DIEP flap between October 1999 and November 2000 were randomly allocated to either a control or exercise group. The exercise group performed pre-operative exercises using the Abdotrim abdominal exerciser. Pre-operatively, outcome measures included trunk muscle strength measured on an isokinetic dynamometer, SF-36, rectus muscle thickness measured using ultrasound, and submaximal fitness. Post-operative pain and length of hospital stay were recorded. Subjects were reassessed using the same outcome measures 1 year post-operatively.

There was a statistically significant increase in static (isometric) muscle strength and thickness pre-operatively for the exercise group. One year following surgery, there was a significant decrease in dynamic (concentric and eccentric) flexion strength for both groups, although the clinical significance of this is questionable as the majority of women

☆ Presented at: The British Association of Plastic Surgeons Winter Scientific Meeting, London, November 28–30, 2001; Interprofessional Masterclass for Breast Reconstruction, organised by the Royal College of Surgeons of England, February 2002; 37th Congress of the Spanish Association of Plastic and Reconstructive Surgery, Oviedo, Spain, June 2002.

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doi:10.1016/S0007-1226(03)00362-X

had returned to pre-operative fitness and the surgery had no impact on functional activities. The static flexion strength of the control group was reduced at 1 year, whereas it was maintained in the exercise group, although this was not statistically significant. One third of women in the control group complained of functional problems or abdominal pain post-operatively compared to one fifth of the exercise group.

Overall, the DIEP flap had no major impact on abdominal muscle strength for either group, demonstrating its superiority over the TRAM flap. There was no statistically significant benefit to the exercise group of the pre-operative exercises 1 year following surgery. However, there was a subjective benefit, albeit statistically nonsignificant, in terms of reduced functional problems post-operatively and improved well-being prior to surgery.

Breast reconstruction is now considered to be an integral component in the management of the breast cancer patient. Free tissue transfer from the abdomen has long been recognised as the gold standard for breast reconstruction. The deep inferior epigastric perforator (DIEP) flap, which requires no muscle resection, has been developed in an attempt to limit damage to the abdominal wall, which was the main disadvantage of the transverse rectus abdominis myocutaneous (TRAM) flap.[1-5] Previous work by the authors[6,7] has shown that the DIEP flap has far less of an impact on abdominal muscle strength and function than the free TRAM flap.

However, with the DIEP flap, scarring in the rectus abdominis muscle secondary to dissecting out the perforators can decrease the contractile potential of the muscle, and disruption of the rectus sheath alters the insertion of the oblique muscles, and therefore abdominal wall complications can still occur.[6] Futter et al.[7] reported that up to 17% of women who had undergone a DIEP flap complained of functional or lifestyle restrictions, and a nonstatistically significant reduction in trunk flexion strength was demonstrated.

The surgery itself has been refined to the extent that no muscle is taken with the perforators. The rectus muscle and fascia are left in place with intact motor innervation. The only improvement that can be made to further minimise damage to the abdominal wall is to use vessels that do not perforate the rectus muscle, as with the superficial inferior epigastric artery (SIEA) flap.[8] However, only a minority of women have superficial vessels large enough to support the amount of tissue required for a breast reconstruction, and therefore this is a limited option. Consequently it is imperative to find new, nonsurgical methods of preventing the post-operative abdominal complications that can result from a DIEP flap, and which preclude women from returning to their pre-operative level of function.

A number of authors include strong abdominal muscles in their criteria for surgery, advocating pre-operative sit-up exercises[9-12] although to date, there has been no research into the effectiveness of this. This study was undertaken to investigate the effect of pre-operative abdominal strengthening as a conservative, noninvasive means of preventing post-operative abdominal complications for women undergoing breast reconstruction with a DIEP flap.

Patients and method

All women who were on the waiting list for a delayed breast reconstruction with a DIEP flap at either Canniesburn Hospital or Gent University Hospital were considered for recruitment. The women were informed about the study by letter or at the Outpatient clinic and invited to participate. Ethical approval was given by the relevant Research Ethics Committees. Informed consent was obtained, and thereafter subjects were randomly assigned to an exercise or a control group with stratification for age (<45 years, ≥ 45 years). Demographic data, plus occupation, and history of abdominal surgery, were obtained.

Both groups underwent an initial assessment. For the exercise group, this occurred approximately 3 months prior to surgery, and for the control group, approximately 1 week prior to surgery. The following outcome measures were used:

- Trunk muscle strength was measured by a blinded assessor on the KIN COM (Glasgow) or Cybex (Gent) isokinetic dynamometer. Concentric and eccentric strength of trunk flexion and extension were measured through range from 15° extension to 40° flexion at 60°/s.

Isometric flexion and extension were measured at 15° extension, 0 and 20° flexion. Three submaximal isokinetic tests were performed first as a warm-up and to allow familiarisation with the machine. The average of three isokinetic tests for each direction was recorded to allow for a learning curve, plus the peak torque achieved. For the isometric tests, one maximal contraction was performed at each interval through range. A maximal effort was strongly encouraged throughout, and a 10 s rest was allowed between each test.

- A submaximal exercise tolerance test was performed using a Cycle Ergometer to establish VO_2 max as a measure of aerobic fitness.
- An ultrasound scan was taken of the abdominal wall by a blinded assessor to measure thickness of the rectus abdominis muscle. The tendinous intersections in the rectus abdominis muscle were identified, and three anatomical positions noted: midway between the pubic symphysis and the lowest tendinous intersection, midway between the lowest and the middle intersections and midway between the middle and upper intersections. At each point, the thickness (AP measurement) of both recti was measured.
- The Short Form 36 Health Survey (SF-36) and a semi-structured interview were used to evaluate mental and physical well-being, plus the impact of surgery on function. Details of the SF-36 in this population are given elsewhere.[7]

The exercise group then underwent a minimum of 6 weeks of straight and oblique curl-up exercises, using the 'Abdotrim'® Abdominal Exerciser. The subject was positioned as shown in Fig. 1. She was taught to perform a posterior pelvic tilt, and then slowly curl forward as far as possible in the device, hold the position for a count of three, then return slowly to the floor. This was repeated with both legs dropped to the right, and then the left.

Fig. 1 Position of subject in Abdotrim exerciser.

These exercises were aimed at increasing both trunk flexion i.e.: dynamic strength (concentric and eccentric), and improving trunk stability i.e.: static (isometric) strength. The eccentric activity of the rectus abdominis forms part of the postural control mechanism that stabilises the trunk. In any activity involving an external resistance in which the trunk is in a position of sustained flexion (e.g. lifting, vacuuming), the rectus is acting eccentrically, in conjunction with the deep stabilising muscles. Concentric activity involves an active shortening of the rectus muscle, which flexes the trunk, as in the curl-up exercise. However, in a standing position gravity acts to flex the trunk. The static tension generated in the rectus abdominis when it is contracting isometrically stabilises and controls the trunk in a standing position to allow the limbs to move independently.

Initially, each exercise was performed 10 times daily, with the number of repetitions increased as able. An instruction sheet of exercises was given to the subjects, plus a daily recording sheet, which was used to monitor exercise progression and compliance. Subjects borrowed the equipment for the duration of the exercise period. A minimum of 6 weeks is required for a training effect.[13] The exercise group then underwent an additional identical assessment approximately 1 week prior to surgery (post-exercise assessment).

During the hospital stay, post-operative abdominal pain levels were recorded daily using a visual analogue pain scale[14] and the type and quantity of analgesia used was recorded. The length of inpatient stay was noted. The same assessment was then repeated 12 months post-operatively.

Statistical analyses

Analyses were carried out in SPSS[15] and Genstat,[16] with a 5% level of significance used throughout. Paired and unpaired *t*-tests and chi-squared tests were used to compare groups between the initial and post-operative assessments, and to compare outcome measures between the initial and post-exercise assessment in the exercise group. Unpaired *t*-tests (SPSS analysis of variance (ANOVA) procedure) were used to test the hypotheses and that there were differences in abdominal muscle strength, muscle thickness, fitness and SF-36 measures between the study groups 1 year post-operatively. In addition, multiple regression analysis was used with each of the 1 year post-operative muscle strength and thickness outcome measures as dependent variable to assess the effect of study group in the presence of other explanatory variables (parity, body mass index (BMI), VO_2 max, age, previous abdominal surgery).

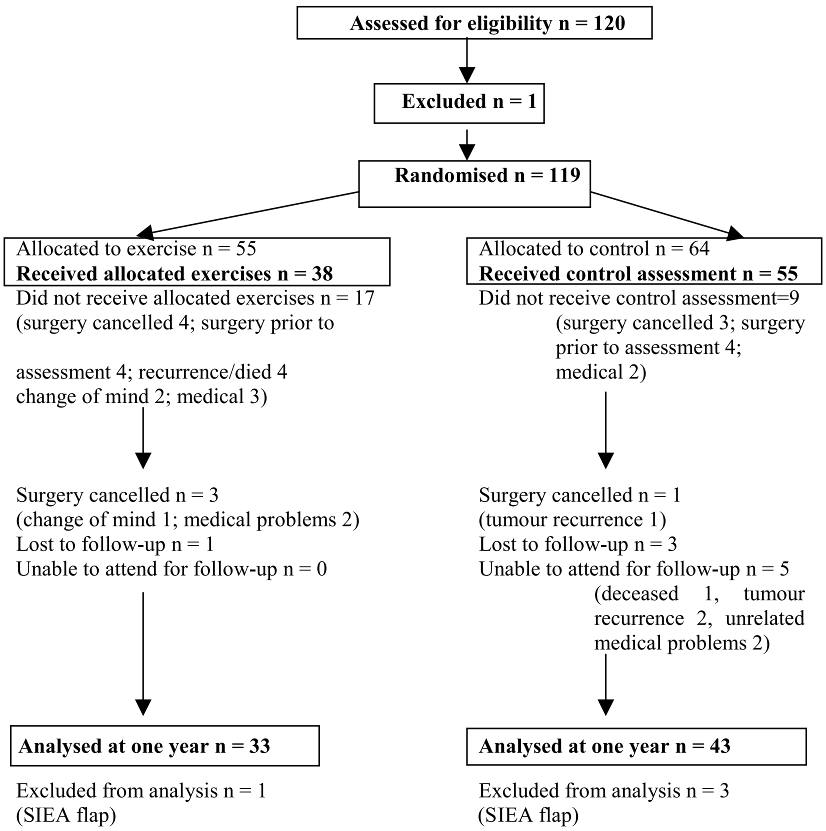

Fig. 2 Flow chart of recruitment and retention of subjects.[25]

Repeated measures analysis[17] was used to examine the effect of surgery on muscle strength irrespective of, and within study group.

Results

Women who were eligible for the study were keen to participate, and most exclusions and drop-outs were due to reasons outwith the control of the study (Fig. 2). Three women in the study had their procedure converted intra-operatively to a TRAM flap. In each case the blood vessels were found to be fragile and therefore a small section of muscle was removed with the blood vessels. Four women in the study underwent a SIEA flap, and as no muscle was removed with the flap, were excluded from all data analysis. There were seven bilateral DIEP reconstructions, two in the control group and five in the exercise group.

Comparison of exercise and control groups pre-operatively. The two study groups were comparable for age, height, weight, BMI, and parity at the initial assessment (Table 1). The majority of women in both groups had not undergone any previous abdominal surgery, with the remainder undergoing most commonly a Caesarian section, hysterectomy or cholecystectomy. There were no statistically significant differences between the groups in muscle strength or thickness, fitness or SF-36 sub-scores.

Compliance with, and impact of, abdominal exercises. In the exercise group, an average of 10 weeks was spent exercising (range 6-33), with a mean total number of daily repetitions of each exercise of 56 (range 20-100). Between the initial and post-exercise assessments, there was a

Table 1 Characteristics of each group at initial assessment—mean and (standard deviation) unless otherwise stated

	Exercise ($N = 38$)	Control ($N = 55$)
Age at surgery (years)	47.59 (6.28)	48.54 (7.07)
Parity (median and range)	2 (0-4)	2 (0-6)
Height (m)	1.61 (0.06)	1.63 (0.06)
Weight (kg)	65.97 (9.08)	69.30 (11.3)
Body mass index	25.33 (3.23)	26.10 (4.40)
VO_2 max (ml/kg/min)	37.84 (8.23)	36.67 (9.49)

Note: initial represents the subject's first assessment—1 week pre-operative for control group and 3 months pre-operative for exercise group.

Table 2 Summary of mean differences in isometric flexion strength and muscle thickness for exercise group between initial and post-exercise assessment (Ax = assessment)

	Initial Ax Mean (sd)	Post-ex Ax Mean (sd)	Paired *t* statistic	df	*p* value
Isometric F 20° (N/kg)	2.39 (1.24)	2.76 (1.28)	3.31	35	0.002
Isometric F 0° (N/kg)	2.21 (1.15)	2.60 (1.32)	3.31	34	0.002
Isometric F −15° (N/kg)	2.13 (1.19)	2.47 (1.28)	2.70	35	0.011
Width BR (mm)	9.23 (2.08)	10.31(2.28)	4.33	18	0.000
Width BL (mm)	9.07 (1.74)	9.90 (2.41)	3.45	18	0.003
Width MR (mm)	8.43 (1.59)	9.16 (2.02)	2.42	18	0.026
Width ML (mm)	8.05 (1.93)	8.84 (1.51)	3.12	18	0.006
Width TR (mm)	8.67 (1.87)	9.26 (1.95)	1.57	18	0.135
Width TL (mm)	8.25 (1.82)	9.04 (1.59)	2.95	18	0.009

statistically significant increase in all the isometric flexion strength measures, and in the muscle thickness for all the measurements except the width at the top right (Table 2). There was a significant correlation between the increase in muscle strength and increase in muscle thickness. There was no change in any of the remaining strength measures, fitness or SF-36 scores.

Immediate post-operative period. Both exercise and control groups spent, on average nine days in hospital ($t = 0.355$; $p = 0.723$). There was no significant difference between the groups in patients' subjective perceptions of abdominal pain post-operatively (results not shown), or in the quantity of analgesia used ($t = 0.939$; $p = 0.352$).

Comparison of outcomes at 1 year post-operative follow-up. The 1 year follow-up assessment was attended by 34 exercise group subjects and 46 control group subjects (Fig. 2).

Muscle strength

At 1 year post-operatively, there was a significant difference between study groups in isometric extension in neutral and isometric extension in extension (Tables 3 and 4). In both cases, the exercise group extension strength was greater than

Table 3 Summary of mean torque for concentric and eccentric flexion and extension at initial and 1 year assessments (w, weight adjusted; p, peak; av, average; con, concentric; ecc, eccentric; f, flexion; e, extension i.e.: Wavconf, weight adjusted average concentric flexion)

		Initial Ax	1 year Ax	ANOVA for group diff. at 1 year	
		Mean (sd)	Mean (sd)	*F* value	*P* value
Wavconf (Nm/kg)	Exercise ($N = 23$)	1.06 (0.39)	1.01 (0.39)	0.130	0.720
	Control ($N = 25$)	1.07 (0.44)	0.96 (0.44)		
Waveccf (Nm/kg)	Exercise ($N = 23$)	1.58 (0.35)	1.46 (0.40)	0.502	0.482
	Control ($N = 24$)	1.65 (0.31)	1.53 (0.28)		
Wpconf (Nm/kg)	Exercise ($N = 33$)	1.24 (0.34)	1.23 (0.35)	0.390	0.534
	Control ($N = 43$)	1.26 (0.36)	1.16 (0.40)		
Wpeccf (Nm/kg)	Exercise ($N = 23$)	1.73 (0.27)	1.66 (0.25)	0.440	0.511
	Control ($N = 25$)	1.80 (0.33)	1.71 (0.24)		
Wavcone (Nm/kg)	Exercise ($N = 22$)	1.03 (0.44)	1.11 (0.36)	3.210	0.080
	Control ($N = 25$)	1.03 (0.49)	0.87 (0.53)		
Wavecce (Nm/kg)	Exercise ($N = 22$)	2.23 (0.48)	2.40 (0.35)	1.994	0.165
	Control ($N = 25$)	2.26 (0.53)	2.23 (0.49)		
Wpcone (Nm/kg)	Exercise ($N = 32$)	1.39 (0.38)	1.40 (0.41)	0.341	0.561
	Control ($N = 43$)	1.47 (0.62)	1.32 (0.63)		
Wpecce (Nm/kg)	Exercise ($N = 22$)	3.16 (0.66)	2.99 (0.53)	0.013	0.909
	Control ($N = 25$)	3.24 (0.68)	3.01 (0.81)		

Note: it is not possible to measure average strength values, eccentric strength or isometric extension strength on the Cybex hence the smaller sample sizes for these measures.

Table 4 Summary of mean isometric flexion and extension strength at initial and one year assessments (all measures weight adjusted)

		Initial Ax	I year Ax	ANOVA for group diff. at 1 year	
		Mean (sd)	Mean (sd)	*F* value	*p* value
Isometric F 20° (N/kg)	Exercise (*N* = 33)	2.37 (1.23)	2.35 (1.21)	0.657	0.420
	Control (*N* = 43)	2.27 (1.25)	1.98 (1.02)		
Isometric F 0° (N/kg)	Exercise (*N* = 33)	2.21 (1.13)	2.12 (1.15)	0.537	0.466
	Control (*N* = 43)	2.07 (1.31)	1.91 (1.10)		
Isometric F − 15° (N/kg)	Exercise (*N* = 33)	2.10 (1.18)	2.13 (1.12)	1.677	0.199
	Control (*N* = 43)	2.10 (1.35)	1.88 (1.26)		
Isometric E 20° (N/kg)	Exercise (*N* = 23)	5.01 (1.49)	5.30 (1.42)	0.164	0.687
	Control (*N* = 25)	5.12 (1.34)	5.12 (1.58)		
Isometric E 0° (N/kg)	Exercise (*N* = 23)	3.38 (0.82)	3.73 (0.85)	6.175	0.017
	Control (*N* = 25)	3.31 (0.94)	3.05 (1.03)		
Isometric E − 15° (N/kg)	Exercise (*N* = 23)	2.99 (0.68)	2.90 (0.84)	5.165	0.028
	Control (*N* = 25)	2.38 (0.76	2.35 (0.83)		

the control group. In the remaining strength measures there was a tendency for the mean to be greater for the exercise group than for the control group. Regressing each strength measure on the various explanatory variables (listed above) confirmed significant differences between exercise and control groups only for isometric extension in neutral and isometric extension in extension measures. That is, the presence of other potential explanatory variables did not highlight any previously masked effects of the intervention.

Muscle thickness

None of the six ultrasound measures of muscle thickness differed significantly between the study groups, although in all cases the mean thickness was greater in the exercise group (Table 5). In the regression models for muscle thickness the inclusion of other explanatory variables did not alter the conclusions regarding differences between study groups.

Fitness and SF-36 sub-scores

There was no significant difference in fitness or any of the SF-36 sub-scores between the exercise and control groups (results not shown).

Repeated measures analyses of muscle strength measures. Analysing initial assessment and 1-year post-operative data using repeated measures models; there was a significant negative effect of

Table 5 Summary of mean width of rectus abdominis muscle measurements at initial and 1 year assessments (B, bottom; M, middle; T, top; L, left; R, right)

		Pre-op Ax	I year Ax	ANOVA for group diff. at 1 year	
		Mean (sd)	Mean (sd)	*F* value	*p* value
Width BR (mm)	Exercise (*N* = 21)	8.98 (2.00)	9.12 (2.01)	0.186	0.668
	Control (*N* = 35)	9.17 (2.06)	8.92 (1.48)		
Width BL (mm)	Exercise (*N* = 21)	9.02 (1.73)	8.88 (2.17)	0.333	0.566
	Control (*N* = 35)	8.99 (1.89)	8.57 (1.76)		
Width MR (mm)	Exercise (*N* = 21)	8.28 (1.75)	9.00 (1.52)	0.508	0.479
	Control (*N* = 35)	8.27 (1.50)	8.71 (1.43)		
Width ML (mm)	Exercise (*N* = 21)	8.03 (1.52)	8.75 (1.67)	0.011	0.915
	Control (*N* = 35)	7.94 (1.30)	8.70 (1.53)		
Width TR (mm)	Exercise (*N* = 21)	8.73 (1.77)	9.72 (2.24)	0.961	0.331
	Control (*N* = 35)	8.37 (1.20)	9.15 (2.04)		
Width TL (mm)	Exercise (*N* = 21)	8.19 (1.78)	9.43 (1.87)	0.358	0.552
	Control (*N* = 35)	8.24 (1.30)	9.12 (2.01)		

time (i.e. surgery) on the muscle strength for the concentric and eccentric flexion measures for both groups (results not shown). In all but one of the concentric and eccentric extension measures, the group*time interaction term tended towards significance and the predicted means from the models suggested a decrease in muscle strength with time in the control but not the exercise group.

Of the isometric measures, isometric extension strength in neutral increased in the exercise group over time but decreased in the control group (significant interaction term).

Subjective outcome measures: relation to abdominal strength measures

Of those subjects who had undergone a unilateral reconstruction, there were complaints of functional problems or tight abdominal scarring from 11% of the exercise group subjects (three women out of 28) compared to 27% of the control group (11 out of 41 subjects), however, this difference was not statistically significant (chi-squared $= 2.672$, df $= 1$, $p = 0.102$). Both the women in the control group who underwent a bilateral reconstruction complained of functional problems compared to three out of five (60%) of bilateral reconstructions in the exercise group. Once the final assessment was completed, eight subjects (18%) in the control group (including the two bilateral reconstructions) required either abdominal strengthening exercises further to complaints of decreased abdominal muscle strength and functional problems, or stretches for tight abdominal scar tissue. This compares with three subjects (9%) in the exercise group, two of whom underwent bilateral reconstructions. This difference was not statistically significant (chi-squared $= 1.365$, df $= 1$, $p = 0.243$).

Discussion

The hypothesis for this trial was that strong abdominal muscles pre-operatively would compensate for any damage to the muscle and prevent post-operative weakness and functional problems. It might be conjectured that any strength gains achieved pre-operatively would be lost in the first weeks post-operatively when the subject was recovering and unable to exercise, and therefore it would have been ideal in addition to investigate the effectiveness of post-operative exercises. Within the first 8 days of disuse, strength loss has been shown to be as much as 6% per day, with minimal loss of strength thereafter.[18] However, as inpatients, the standard post-operative physiotherapy regime included posterior pelvic tilting from the second or third post-operative day, which would have produced a submaximal contraction of the lower rectus muscle. This muscle activity in the early post-operative period would go some way towards preventing the muscle atrophying to the extent that the benefit of the pre-operative exercises was negated. Furthermore, post-operative complications such as delayed wound healing and infection would make standardising a post-operative intervention more difficult.

Two different types of isokinetic dynamometer were used to measure trunk muscle strength, the KIN COM in Scotland and the Cybex in Belgium. However, both machines have been shown previously to have intra and inter-operator reliability, and assessment protocols and instructions were standardised. Fewer strength measures were available for the Belgian subjects as it is not possible to measure average strength values, eccentric strength or isometric extension strength on the Cybex.

The curl-up exercise involves curling the chin onto the chest and then curling the trunk forward until the inferior scapular angles are raised, whilst maintaining a posterior pelvic tilt. The curl-up was chosen for the intervention because it has been shown to be an effective means of strengthening upper and lower rectus abdominis.[19,20] It has also been demonstrated that using a training device such as the Abdotrim is as effective as the standard curl-up,[21–23] and that motivation is improved for subjects exercising with such a device as opposed to without.[23] The abdotrim was selected because it is comfortable and easy to use, portable and cheap. Exercise technique is standardised, and the subject's neck is supported thus preventing potential neck pain. Furthermore, it was important to choose an intervention that would be easy to teach in the clinical setting, and which subjects could perform easily and safely at home. Subjects were instructed to perform the exercises slowly to develop greater isometric abdominal strength.[24]

Compliance with the exercise programme was generally high. All the women were keen to do what they could to prepare for their surgery, and did appreciate being able to take the Abdotrim home. There was a significant increase in static (isometric) flexion strength following the exercise period, but not the anticipated improvements in dynamic (concentric or eccentric) flexion strength. This might in part be due to the relatively short exercise period. However, anecdotally, many of the subjects commented that the exercises had become much easier to perform towards the end of the exercise period, and the exercise diaries showed an increase in repetitions for all subjects. The increase in muscle thickness noted following the exercise period corresponds to the increase in static strength in that static strength is related to cross-sectional muscle thickness.[18] The general fitness of the subjects did not change during the exercise period, adding to the likelihood that the strength gains were due to the intervention. The majority of subjects commented that the exercises had enabled them to feel well prepared for their surgery, both physically and mentally, although this is entirely subjective.

There was no difference in length of hospital stay between groups, neither in abdominal pain nor analgesia use. However, it was perhaps unrealistic to expect a reduction in pain for the exercise group because, although it was hoped that the exercises would increase muscle thickness and vascularity, both groups had the same large abdominal wound, the main source of pain. Equally, discharge from hospital was largely determined by when drains were removed, and the intervention was not going to influence this.

There was a significant negative effect of time on the concentric and eccentric muscle strength of both groups, suggesting that the surgery was having a detrimental effect on dynamic abdominal muscle strength with no additional benefit to the exercise group from the pre-operative exercises. Several conclusions can be suggested from this. Although no muscle is removed with the DIEP flap, scarring still occurs in the muscle, and the results of this study suggest that this has an impact on abdominal muscle strength. Equally, the dynamic flexion strength of the exercise group did not increase significantly following the exercises and thus it is of little surprise that both groups demonstrate a decrease in these measures post-operatively.

However, although the effect of time was statistically significant, looking at the other outcome measures suggests that this is of less clinical importance. There was no significant difference in the fitness of the subjects post-operatively, which would indicate that, except for those with specific functional problems, as discussed later, the majority of the women had returned to the level of activity enjoyed pre-operatively. Equally, there were no differences in scores on any of the SF-36 sub-scales, which include a measure of how health affects physical activity and physical function. This further indicates that despite a decrease in dynamic flexion strength noted at 1 year, the majority of women were able to compensate for this and it did not affect their function or activities of daily living. Furthermore, the trend post-operatively was for the mean dynamic flexion strength of the exercise group, and the mean muscle thickness at all points, to be greater for the exercise group than for the control group. So although there was not a statistically significant increase in dynamic strength for the exercise group pre-operatively, there may be a trend towards a protective effect of the exercises in minimising the reduction in strength post-operatively.

The surgery had less impact on the isometric, or static, flexion strength of both groups. Although there was no statistically significant difference between the two groups at 1 year, the mean static strength and muscle thickness for the exercise group (which increased as a result of the exercises) tended to increase or show little change post-operatively compared to the initial assessment. This is in contrast with the control group, where there was a tendency towards a decrease in both mean static strength and muscle thickness. None of these results were statistically significant, but the indication is that the exercise group may have benefited from the increase in isometric strength achieved as a result of the exercises. Isometric activity of the rectus abdominis has an important functional role. In conjunction with the deep stabilising muscles, it helps to stabilise, control and protect the trunk during functional activities including lifting. In addition, in any activity in standing, the rectus abdominis is working statically to support and control the trunk whilst allowing the limbs to move independently.[18]

There were specific complaints of functional problems or abdominal pain/tightness 1 year following surgery from one third of women in the control group, compared to less than one fifth of those in the exercise group. Reported problems included difficulty vacuuming, lifting, inability to continue a job that involved heavy lifting, and subjective reports of decreased abdominal strength. Although a subjective outcome measure and not statistically significant, this may suggest a beneficial effect of the pre-operative exercises. This could be due to the maintained static flexion strength observed in the exercise group which, as discussed above, has an important postural and stabilising role.

Both of the women in the control group who underwent bilateral reconstructions, in which both rectus abdominis muscles are affected, reported functional difficulties following surgery, and required additional physiotherapy following their final assessment. This compares with two out of five of the women in the exercise group who underwent a bilateral reconstruction, perhaps again suggesting a benefit in terms of maintained muscle strength for the exercise group.

It is interesting to note the effect of surgery on the strength of the back extensors (isometric extension in neutral and extension). The isometric strength of the back extensors of the exercise group was significantly greater 1 year post-operatively than the control group. It was anticipated that the extension strength of the exercise group would not be affected by the exercises as they were aimed at strengthening the abdominal muscles only and therefore would only influence flexion strength. However, it is impossible to isolate abdominal muscles from the back extensors as the abdominal muscles (except rectus abdominis) attach into the thoracolumbar fascia, which forms part of the back extensor mechanism. It is therefore postulated that strengthening the abdominal muscles pre-operatively (the obliques with the diagonal curl-up exercises, and transversus abdominis to a lesser extent with the posterior pelvic tilt) provided protection to the spine which may indirectly have contributed to increased back extension strength.

This is the largest prospective study carried out investigating abdominal strength following a DIEP flap. Previous studies have demonstrated a significant abdominal weakness following a TRAM flap[6,7] but the results from this trial indicate that, overall, the impact on abdominal strength and function following a DIEP flap is minimal. The majority of women in both groups stated they were back to normal within a few months of surgery, with no change noted in fitness or health-related physical function compared to their pre-operative levels and was delighted with the outcome. For those undergoing pre-operative strengthening exercises, there was an additional subjective benefit in terms of maintained static flexion strength and fewer functional problems post-operatively, plus a greater sense of well-being and physical and mental preparation prior to surgery.

Acknowledgements

We would like to thank all the women who participated in the study for giving up their time so readily, the Scottish Executive for funding the work, Sarah Mitchell for conducting the KIN COM assessments in Scotland, and Justwise Group for providing the Abdotrim Exercisers. We would also like to thank Professor Dr R. Lysens and the physiotherapists of the CERM of the University Hospitals of Leuven for their participation and support. Additionally, thanks are extended to the sports medicine team of the University Hospital of Gent.

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