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Original research

Insight Into the Effect of Hospital-Based Prehabilitation on Postoperative Outcomes in Patients With Total Knee Arthroplasty: A Retrospective Comparative Study

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ABSTRACT

Background: Osteoarthritis (OA) has become one of the most prevalent joint diseases worldwide, leading to a growing burden of pain and disability as populations age. Although there is consistent evidence to support postoperative rehabilitation and high-intensity prehabilitation for total knee arthroplasty (TKA), the clinical outcomes of hospital-based prehabilitation remain unclear. We aimed to evaluate the effect of a hospital-based prehabilitation program on knee score (KS), function score (FS), and length of stay (LOS) among patients with knee OA after TKA.
Methods: A retrospective comparative study was conducted at Renmin Hospital of Wuhan University among patients with primary knee OA. Seventy-two postopearive patients who did not undergo the prehabilitation program were included as the control group, while 68 postoperive patients who underwent the prehabilitation program were assigned to the intervention group. All patients went through the same care after TKA. The KS, FS, and pain levels were measured 5 days before surgery, immediately preceding surgery, immediately after the surgery, and at 1 week and 1 month postoperatively. LOS for each patient was recorded.
Results: The new prehabilitation training program significantly improved the KS over time in the intervention group. However, no significant between-group difference was identified in the change of FS. The prehabilitation program also provided shorter LOS.
Conclusions: The hospital-based prehabilitation program leads to improved recovery, as indicated by higher KS postoperatively, which may result in improved clinical outcomes of TKA.
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Introduction

In response to upward-shifting population demographics, osteoarthritis (OA) prevalence and incidence are rising [1]. OA is now one of the most prevalent joint diseases worldwide [1]. This disease causes knee pain and impairs function, which hamper patients' physical functions and general health [2]. The most common

treatment for end-stage OA is total knee arthroplasty (TKA) surgery, which is effective in reducing pain and improving function [3].

Despite the overall satisfactory results after TKA, dissatisfaction and persistent postsurgical pain occur in up to 44% of cases [4]. A prospective cohort study has demonstrated that patients had significantly lower functional abilities in the early postoperative period than in the preoperative period [5]. To tackle postoperative problems, prehabilitation helps patients to cope with stress and practice training before surgery and then to equip them with the skills to complete rehabilitation training immediately after TKA and accelerate recovery [6]. Prehabilitation has been shown to be an effective way to reduce length of stay (LOS) and help patients

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reduce dependence on caregivers sooner [6,7]. Researchers have also found that prehabilitation accelerates functional recovery and reduces additional health-care costs [8].

In recent years, randomized clinical trials (RCTs) have supported the proposition that prehabilitation programs would lead to prominent improvements in outcomes of TKA, including knee flexion improvement and pain reduction among patients with OA [9,10]. However, no associations between prehabilitation and functional recovery or quality of life have been found [11-14]. In the preoperative period, prehabilitation is associated with better mental health, walking ability, and muscle strength [15]. In most studies, the prehabilitation duration was 4 to 6 weeks and led to positive clinical outcomes such as increased muscle strength [9,11,14-17]. These clinical benefits were more prominent in long-duration high-intensity prehabilitation programs than in the relatively short-duration low-intensity ones [18,19].

To our knowledge, the clinical outcomes of hospital-based prehabilitation remain unclear. Some researchers have suggested that disparities in intensity and duration may explain the equivocal findings on the association between prehabilitation and improved postsurgical outcomes [15,17,20]. Most research on prehabilitation has looked at home-based training [21], with fewer studies focused on hospital-based training. In addition, studies have typically not focused on recovery during hospitalization or have done so only to a limited extent. Therefore, we aimed to explore the effects of a hospital-based prehabilitation program among patients undergoing TKA. We hypothesized that this prehabilitation program would lead to greater improvements in knee pain, knee flexion, knee extension, and functional ability measures after TKA compared with the control group.

Material and methods

Study participants

Patients older than 60 years with knee OA who had gone through unilateral TKA at the Renmin Hospital of Wuhan University (RHWU) between March 31, 2018, and November 1, 2019, were eligible for this study. Patients with contralateral limb pain or previous hip or knee joint surgery were excluded from the study. We also excluded patients who had illnesses associated with limited functional performance and exercise.

Trial design

This study was a retrospective comparative study conducted at the RHWU. The purpose and content of the prehabilitation were included in the education session conducted before the training. The research was reviewed, monitored, and approved by the Institutional Review Board at RHWU. The Department of Orthopedics at RHWU started preoperative education and prehabilitation for all OA patients who had been scheduled for surgery as of February 11, 2019. According to the records, no patient refused the education and prehabilitation. Among eligible patients before February 11, 2019, they did not undergo prehabilitation and were assigned to the control group. All other eligible patients did undergo prehabilitation and were included in the intervention group. The researchers collected data from hospitalization and surgery records.

Prehabilitation

Prehabilitation is a 5-day preoperative program. It aims to help patients master the rehabilitation training exercises they will engage in after surgery to enhance perioperative functional capacity to accelerate recovery. Prehabilitation includes both education and training sessions. The education session is designed to improve awareness of the importance of postoperative rehabilitation training after TKA through physical therapists' verbal instructions.

In the training program, an experienced physical therapist supervised and guided patients to exercise their own lower limb muscles. Each patient in the study was encouraged to complete the daily training. However, the physical therapist, in some cases, adjusted the intensity level according to the patient's specific situation. The training session started with a 10-minute warmup. During these 10 minutes, the physical therapist massaged and measured the legs to provide the doctors with information about recovery. The training session included inner range quadriceps, heel slides, isometric quadriceps, ankle pumps, and straight leg raises (Table 1).

Usual care

All patients received standardized perioperative care, except the control group which did not receive prehabilitation. Both the control and the intervention groups were treated with the same conventional postoperative care. The surgeons checked the patients' knees and sutures every day. The control group received verbal rehabilitation instructions immediately after TKA, but no demonstration of rehabilitation was provided. All the patients were encouraged to complete the same postoperative training program after TKA.

Outcomes

The primary outcomes were knee score (KS) and function score (FS). These 2 scores were measured according to the American Knee Society Clinical Rating System [22], and the pain was measured by the Visual Analog Scale for pain (VAS). KS is a composite of pain, total range of flexion, stability, flexion contracture, extension lag, and alignment [23]. FS is a composite of walking, stairs, and walking aids used [23]. This system is one of the most well-known and commonly used outcome measure tools [24]. The validity and reliability had been extensively studied [24]. According to a validation study, the rating system has adequate validity [25]. The secondary outcome, LOS, was defined as the time from hospital admission to discharge.

The repeated assessments for each patient were evaluated at 4 time points as follows: Baseline was measured before the prehabilitation programs and before surgery, the second testing was measured before the surgery, the third testing was at 1 week after TKA, and the fourth testing was at 1 month after TKA. The American Knee Society Clinical Rating and VAS scores were used by the assessors to complete assessments.

Statistical analysis

The primary outcomes included the KS and FS score changes from the baseline to 1 month after the surgery. A previous study

Table 1
Preoperative training of the prehabilitation group.

Exercise	Description
Inner range quadriceps	Hold for 5-10 s, 4 sets of 25 repetitions
Heel slides	Hold for 5-10 s, 5sets of 20 repetitions
Isometric quadriceps	Hold for 5-10 s, 10 sets of 3 repetitions
Ankle pumps	10 sets of 5 repetitions in 4 directions
Straight leg raise leg raised to 45°-60°	3 sets of 20 repetitions

using the same scoring system showed that the means and standard deviations of clinical judge change, pain change, and FS change at 6 months are 16.0 ± 11.2, 30.4 ± 15.2, and 17.9 ± 19.5, respectively [24]. Given that the sum of clinical judge and pain is equal to KS, we assumed the mean and standard deviation of KS score change and FS score change in the control group are 46 ± 15 and 18 ± 20. Using a two-sided two-sample equal-variance t-test at a significance level of 5%, 68 patients per group achieved 80.0% power to test a mean difference of 7.3 with a standard deviation of 15 for KS change and a mean difference of 9.7 with a standard deviation of 20 for FS change. All statistical analyses were conducted using SAS (version 9.4, SAS Institute, Cary, NC) at the two-sided 5% significance level. Descriptive statistics were calculated for baseline characteristics between the 2 groups. Chi-square tests were used to compare the differences of categorical variables between 2 groups. t-tests Were also performed to assess the differences in KS, FS, and LOS between groups at each time point. Generalized linear mixed models were used to analyze the longitudinal data, which considered the correlation from the repeated measures within the same patients. An unstructured correlation structure was used because this model has the smallest Akaike information criterion value and a -2 Log-Likelihood score. The group, time, and the group-time interaction factors were included in the model. We adjusted for age, gender, Body Mass Index (BMI), residence, diabetes, and hypertension in the models. The *P* values of the group-time interaction factors were estimated to assess whether the KS and FS across all time points between the 2 groups differed significantly. Least-square mean differences between 2 groups for each outcome at each time point were estimated, and 95% confidence intervals were calculated when accounting for within-patient correlation and other relevant factors.

Results

A total of 168 patients were eligible for our study; 15 patients were excluded because they were younger than 60 years, and 13 patients were excluded because of missing data. There were no significant differences in the baseline data between the intervention and control groups (Table 2). Most of the patients were women: prehabilitation group ($n = 68$; 35.3% men, 64.7% women) and control group ($n = 72$; 30.6% men, 69.4% women). Most of the patients were aged 66-75 years with BMIs ranging from 20 to 25. Over 80% of patients were residents in Wuhan. There were no significant differences in diabetes and hypertension rates between the 2 groups.

The descriptive analysis showed that the 2 groups had a similar KS at the baseline (33.0 ± 4.1 vs 32.8 ± 4.1; $P = .77$). At any

Table 2
Baseline characteristics of 140 post-TKA surgery patients at Renmin Hospital Wuhan University, China.

Characteristic	Prehabilitation ($N^a = 68$) N (%)	Control (N = 72) N (%)	P value[b]
Gender			.55
Male	24 (35.3)	22 (30.6)	
Female	44 (64.7)	50 (69.4)	
Age			.42
≤ 70	33 (48.5)	24 (33.3)	
> 71	35 (51.5)	48 (66.7)	
BMI			.53
≤ 23	28 (41.2)	40 (55.6)	
> 23	40 (58.8)	32 (44.4)	
Diabetes	29 (42.6)	23 (31.9)	.19
Hypertension	47 (69.1)	53 (73.6)	.56
Native	58 (85.3)	62 (86.1)	.89

[a] N = Number.
[b] Chi-square or Fisher's exact test.

postbaseline time point, patients in the intervention group had a statistically greater KS than the patients in the control group ($P < .05$) (Table 3). In the generalized linear mixed models adjusted for age, gender, BMI, residence, diabetes, and hypertension, both the prehabilitation group and the control group had significant variances in KS and FS over time ($P < .01$) (Figs. 1 and 2). However, between-group interactions over time were present in KS ($P < .001$) but not in FS ($P = .23$) (Figs. 1 and 2). For the adjusted variables, hypertension was significant in the model of KS ($P < .05$), and gender was significant in the model of FS ($P < .05$). Both KS and FS were significantly greater in the group with the prehabilitation program at T2, T3, and T4 (Table 4).

In the intervention group, baseline KS was 32.9 (31.9 to 33.9), KS immediately before the surgery was 33.7 (32.1 to 35.3), postoperative KS was 65.4 (64.1 to 66.7), and 1-month postoperative KS was 74.5 (73.3 to 75.8), while in the control group, baseline KS was 32.9 (31.9 to 33.8), KS immediately before surgery was 31.1 (29.5 to 32.6), postoperative KS was 49.3 (48 to 50.5), and 1-month postoperative KS was 61.4 (60.1 to 62.6). The mean differences were -0.1 (-1.4 to 1.3), -2.6 (-4.8 to -0.5), -16.1 (-17.9 to -14.3), and -13.2 (-14.9 to -11.4), respectively. Both groups had a similar FS in the first and second measurements. In the first measurement (baseline), the intervention group FS was 22.2 (18.7 to 25.7), and the control group FS was 20.6 (17.2 to 24) ($P = .5$). Immediately before surgery, the intervention group FS was 29.2 (25.9 to 32.5) and 25.1 (21.8 to 28.3) in the control group ($P = .08$). However, postoperative mean FS scores were statistically significantly different between groups. The 1-week postoperative FS of the intervention group was 40.3 (38.5 to 42.2) vs 35.5 (33.7 to 37.3) in the control group ($P < .001$). The 1-month postoperative FS was 55.9 (54.7 to 57.1) in the intervention group vs 49.6 (48.4 to 50.8) in the control group ($P < .001$). The mean difference was -1.6 (-6.5 to 3.3), -4.2 (-8.8 to 0.5), -4.8 (-7.4 to -2.3), and -6.3 (-8 to -4.5), respectively.

There was a statistically significant difference in the LOS; the mean of the intervention group was 15.17 ± 4.7 days, while the mean of the control group was 19.6 ± 8.9 days ($P < .001$).

Discussion

The main finding was that the new prehabilitation programs significantly improved the KS over time compared with the control group. Moreover, patients in the intervention group had shorter LOS. However, no significant between-group differences were found in the FS across 4 time points.

The finding that this intervention has a significant effect on KS across the time points but had no significant effect on FS in the short term is consistent with previous studies [17]. These results indicate that prehabilitation programs improve physical recovery better than functional recovery in the early postoperative periods. It is possible that notable functional improvements resulting from rehabilitation programs do not emerge until at least 3 months after surgery. Consistent with this explanation, some cross-sectional studies have suggested that the positive association between range of motion (ROM) and functional performance after TKA was not notable until 1 or 2 years after surgery [21,26]. In recent years, many RCTs showed that various high-intensity prehabilitation programs, such as faster physical and functional recovery, lead to positive outcomes for patients after TKA by relieving pain and strengthening lower limb muscle as well as improving ROM and functional task performance [9,17]. However, fewer studies indicated that hospital-based prehabilitation programs lead to similar positive outcomes. One reason for the difference in outcomes was the different scoring systems used to evaluate the effects of prehabilitation on postoperative outcomes [27]. Most studies measured the outcome using the Western Ontario and McMaster

Table 3

Descriptive statistics for knee score and functional score by time points and LOS among 140 post-TKA surgery patients at Renmin Hospital Wuhan University, China.

Variables	Time point	Mean (95% CI)		Between-group difference (95% CI)
		Control group	Intervention group	
Knee score	Baseline (T1)	32.8 (31.8 to 33.8)	33.0 (32.0 to 34.0)	−0.2 (−1.6 to 1.2)
	Before the surgery (T2)	31 (29.4 to 32.6)	33.8 (32.3 to 35.3)	−2.8 (−5 to −0.6)[a]
	1 wk after the surgery (T3)	49.2 (48.0 to 50.4)	65.4 (64.1 to 66.8)	−16.2 (−18.1 to −14.4)[a]
	1 mo after the surgery (T4)	61.3 (60.1 to 62.6)	74.6 (73.3 to 75.9)	−13.3 (−15.1 to −11.5)[a]
Function score	Baseline (T1)	20.5 (16.9 to 24.1)	22.4 (18.9 to 25.8)	−1.9 (−6.8 to 3.1)
	Before the surgery (T2)	24.9 (21.5 to 28.4)	29.3 (26.1 to 32.5)	−4.4 (−9.1 to 0.3)
	1 wk after the surgery (T3)	35.4 (34.1 to 36.7)	40.4 (38.2 to 42.7)	−5.1 (−7.6 to −2.6)[a]
	1 mo after the surgery (T4)	49.5 (48.4 to 50.6)	56.0 (54.6 to 57.4)	−6.5 (−8.3 to −4.8)[a]
Length of stay		15.6 (13.5 to 17.7)	11.2 (10.0 to 12.3)	4.4 (2.0 to 6.8)[a]

[a] Significant between-group difference using independent t-test.

Universities Osteoarthritis Index, LOS, VAS, ROM, and Knee Injury and Osteoarthritis Outcome Score scale. These scoring systems do not output a composite score. Researchers focus on the difference of single factors in the analysis. However, a single index may not accurately or completely represent a comprehensive knee condition. For example, patients in the intervention group could hypothetically have lower ROM, but with lower pain and higher stability. It would, therefore, be one-sided to attempt to capture the full effect of prehabilitation using ROM alone. In the Knee Society Clinical Rating System (KSCRS), ROM, stability, flexion contracture, extension lag, and alignment are scored according to weight, and the total score represents the comprehensive knee condition. KSCRS is a simple method to assess the knee and functional abilities objectively [22,28]. KSCRS has received praise from clinical physiotherapists [29]. However, to our knowledge, few studies have used KSCRS to report longitudinal TKA results. This study obtained composite scores from KSCRS to measure the TKA outcome.

Another reason that existing research has not, thus far, found enough evidence for hospital-based prehabilitation programs concerns differences in the measurement time points for postsurgical outcomes. Most of the studies collected the outcomes at 3 months after TKA, or even years after TKA [30]. However, considering the cost of hospital stays and enhanced recovery after surgery [31], we were interested in investigating the effect of early rehabilitation in this research. KS and FS are measured at 7 days and 1 month after TKA surgery. The results presented here build on the findings of a previous study which suggested that the prehabilitation programs benefit the short-term postoperative recovery of ROM for OA patients after TKA [21]. Finally, the effect of exercise might be limited because of insufficient or nonstandard training. The intervention setting was stricter in this study than the previous studies. A strength of this study was that the patients conducted the training program with an experienced physical therapist in the hospital environment. However, in other studies,

patients undertook home-based exercise programs [21]. Compared with the home-based program group, Remedios found a greater improvement of knee recovery in the hospital-based group [32]. This finding suggests that patients may not complete training because of place, thus the home-based exercise program is not as effective when compared to a hospital-based program. Patients in the prehabilitation program had a LOS that was 4.5 days shorter than the LOS among those in the control group. Our conclusion is similar to the one reached by a 2017 RCT, which found that patients who completed a high-intensity prehabilitation program saw a 2-day reduction in LOS compared with controls [9].

Our prehabilitation program improved participants' awareness of postoperative training through health education and then taught them scientific exercise methods. Increased awareness usually pushes patients to practice healthy behaviors and stick to advise from physicians [33]. After the health education, these patients could take advantage of the 5-day training to master the correct exercise methods, and these exercises could improve knee recovery better and in a short period.

During our past clinic practice, some patients even believed that the painful training program was harmful to their recovery after TKA. The control group was treated with rehabilitation guidance and training after TKA. According to our observation and investigation, patients are often reluctant to move after TKA because of a lack of awareness of rehabilitation's importance, as well as fear of pain associated with movement. Examples of concerns expressed by patients in our study included the belief that moving could interfere with wound healing, worsen postoperative pain, and cause discomfort, or displace the monitor, surgical drains, or urinary catheters. In the intervention group, patients were treated with preoperative education and training. Their better KS recovery relative to controls suggested that the patients in the treatment group were more likely to complete the rehabilitation training after TKA. Preoperative education and training may help patients by

Table 4

Generalized linear mixed models for knee score and functional score among 140 post-TKA surgery patients at Renmin Hospital Wuhan University, China.

Variables	Time point	Least square mean (95% CI)		P value for group by time interaction	Between-group difference (95% CI)
		Control group	Intervention group		
Knee score	Baseline (T1)	32.9 (31.9 to 33.8)	32.9 (31.9 to 33.9)	<.01	−0.1 (−1.4 to 1.3)
	Before the surgery (T2)	31.1 (29.5 to 32.6)	33.7 (32.1 to 35.3)		−2.6 (−4.8 to −0.5)[a]
	1 wk after the surgery (T3)	49.3 (48.0 to 50.5)	65.4 (64.1 to 66.7)		−16.1 (−17.9 to −14.3)[a]
	1 mo after the surgery (T4)	61.4 (60.1 to 62.6)	74.5 (73.3 to 75.8)		−13.2 (−14.9 to −11.4)[a]
Function Score	Baseline (T1)	20.6 (17.2 to 24.0)	22.2 (18.7 to 25.7)	.23	−1.6 (−6.5 to 3.3)
	Before the surgery (T2)	25.1 (21.8 to 28.3)	29.2 (25.9 to 32.5)		−4.2 (−8.8 to 0.5)
	1 wk after the surgery (T3)	35.5 (33.7 to 37.3)	40.3 (38.5 to 42.2)		−4.8 (−7.4 to −2.3)[a]
	1 mo after the surgery (T4)	49.6 (48.4 to 50.8)	55.9 (54.7 to 57.1)		−6.3 (−8.0 to −4.5)[a]

All the statistics were estimated after adjusting for age, gender, BMI, residence, diabetes, and hypertension.

[a] Statistically significant between-group difference ($P < .05$).
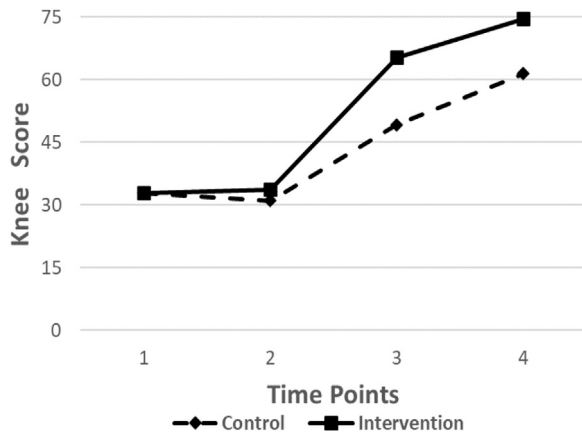
Figure 1. The trends of knee score across 4 time points in control and prehabilitation intervention groups among 140 patients after TKA at Renmin Hospital Wuhan University, China. Least square estimates from generalized linear mixed models adjusting for age, gender, BMI, residence, diabetes, and hypertension. T1 refers to 5 days before surgery; T2 refers to the day when patients completed the prehabilitation program before the surgery; T3 refers to 1 week after TKA; T4 refers to 1 month after TKA.

Figure 2. The trends of function score across 4 time points in control and prehabilitation intervention groups among 140 patients after TKA at Renmin Hospital Wuhan University, China. Least square estimates from generalized linear mixed models adjusting for age, gender, BMI, residence, diabetes, and hypertension. T1 refers to 5 days before surgery; T2 refers to the day when patients completed the prehabilitation program before the surgery; T3 refers to 1 week after TKA; T4 refers to 1 month after TKA.

reducing the fear of pain and improving the awareness of rehabilitation's importance. In clinical practice, preoperative training helped patients find appropriate strategies to maintain effective exercise levels after TKA.

We conducted a retrospective comparative study to assess the impacts of a hospital-based prehabilitation program on knee recovery. The study design may have helped us infer causality or avoid spurious conclusions [34] because it followed patients over time. Hospital-based training is another strength of this research. Patients can avoid injury, follow their own preferences for exercise style, and learn scientific and correct exercise methods under the supervision of physical therapists. This study also had some limitations. First, our research had a relatively small sample size because of new regulations implemented starting in 2019. As a result of which, the power of detecting negative findings in the FS models is low (<0.8). Second, the surveyors could not be blinded, and therefore, information bias could not be eliminated. Finally, the conclusions may not be generalizable to long-term recovery after TKA. Because this study did not measure the completion of the training program after TKA, future studies should focus on the effect of the prehabilitation program on the completion of postoperative training.

Conclusions

Our study demonstrated that a hospital-based prehabilitation program had significant, positive effects on knee recovery after TKA. The prehabilitation was hospital-based and consisted of preoperative education and 5-day training. The prehabilitation group had a higher KS, which indicated lower postoperative pain, better ROM, and increased knee stability. However, no association between prehabilitation and FS was found. In summary, we recommend this hospital-based prehabilitation because it may shorten the length of hospital stay by enhancing knee recovery after TKA.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.
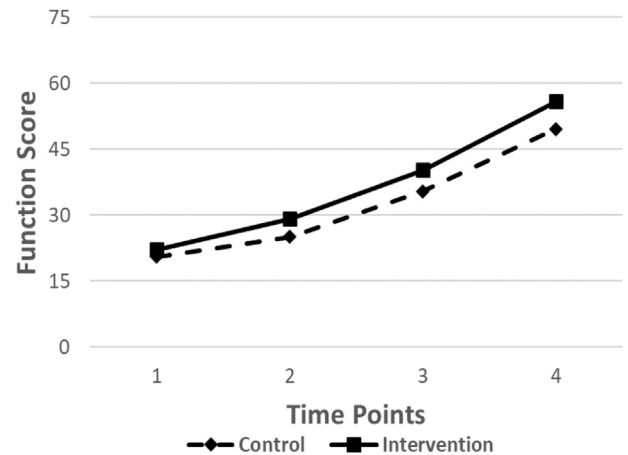
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