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Intelligent knee physical therapy approach with monitoring of gains in strength and mobility of the muscles

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Abstract: Knee is one of the most important joints of the lower limb and it can be affected by various medical conditions with impact on its function. Intelligent system-based exercise therapy is a modern method of regaining knee function, but no previous studies have explored its potential benefits in knee rehabilitation. The objective of this study was to investigate the short- and long-term effects of the exercises with intelligent systems on knee function in patients with osteoarthritis, patellofemoral syndrome and knee instability. A total of 60 patients suffering from one of these conditions (32 with osteoarthritis, 21 with knee instability, 7 with patellofemoral syndrome) were treated with two intelligent systems for 2 weeks. Two parameters, namely knee mobility and isometric muscle strength, were measured at the beginning of therapy, immediately after therapy, after 6 months and after 12 months. All measured parameters showed improvement at the end of the exercise therapy. Knee mobility in both extension and flexion decreased slightly at 6 months (-2.73◎±1.043◎ and -0.09◎±0.005◎, respectively) but increased again at 12 months (3.05◎±1.105◎ and 2.61◎±1.321◎, respectively). Muscle strength for extension and flexion was improved after therapy but decreased progressively in time. In conclusion, intelligent systems - based exercise therapy produced improvement of the knee function in all patients, but muscle strength decreased in time, suggesting the need for repeating the therapy or for a better adherence of the patients to a program of exercises for maintaining the gain.

Keywords: intelligent exercise system, exercise therapy, osteoarthritis, knee instability, patellofemoral syndrome

1. Introduction

The knee is among the largest joints of the lower limb, involved both in supporting the body mass and in performing various daily activities or some more demanding ones such as those encountered in sports and employment. It plays an important role in the multiplanar movement of the lower limb (flexion, extension and internal/external rotation) during these activities. Any dysfunction that may occur in any of its main components (bone, cartilage, ligaments and fluid) or in the muscles and tendons that support it can affect its function, causing pain and difficulty in moving with a significant impact on quality of life. The most common injuries to which the knee joint is subjected are: soft tissue tears (e.g., ligament tears (anterior cruciate ligament, posterior cruciate ligament, lateral collateral ligament, medial collateral ligament), muscle tears (quadriceps, thigh adductors) and tendon tears (patellar tendon)), fractures (patellar and tibial plateau fractures), and dislocations (knee, patellar and meniscus dislocations) [1–3]. Some of these lesions may appear during the aging process leading to osteoarthritis. Management recommendations for these knee diseases most often include:

pharmacological treatment, articular immobilization (hinged knee brace), physical therapy, arthroscopic surgery, and open surgery [4–8].

Physical therapy, also known as physiotherapy, is a widely recommended option as a non-surgical treatment for knee conditions but also for surgical cases as pre-habilitation treatment (before surgery) or postoperative rehabilitation, for recovery after knee surgery [4–8]. By combining specific exercises or device-based exercises with manual therapy and other electrophysical modalities based on ultrasound, electricity, laser radiation, heat, etc., physical therapy has proved to play an important role in restoring knee function and strengthening the thigh muscles that support it, with an impact on improving the patient's ability to perform daily or work activities.

Exercise therapy, as part of physical therapy, is often recommended as a first-line of treatment, especially for non-surgical knee conditions. Its effectiveness in relieving pain, improving mobility, strengthening muscles, and post-operative knee rehabilitation is well known and strongly supported by numerous scientific evidence [9–16]. Despite this, exercise therapy alone or combined with various devices (e.g., treadmill, gait training equipment, continuous passive motion machine) remains an underused therapeutic modality in primary care of some knee conditions, especially osteoarthritis, one of the most common knee diseases for which most clinical research highlights an overuse of pharmaceutical treatments [17–20]. Instead, exercise therapy is recommended as "core" treatment for knee osteoarthritis in many clinical guidelines [21–23].

Although exercise therapy is well-recognized in the treatment of various knee conditions, its effectiveness is influenced by treatment parameters, studies 'quality, patient adherence, the severity and type of the knee condition, and psychological components (the patient's individual conditions) [24–26]. However, with proper implementation of exercise therapy (supervision, personalized treatment, psychological support, etc.) optimal results can be achieved. Even so, there is still a need to develop new modalities to establish treatment parameters (type, duration, frequency, and intensity of exercise) and to subjectively/objectively assess exercise outcomes (knee pain and function) [27,28].

Technological advances and the development of intelligent exercise systems, such as the David systems, may help physicians solve these tasks and add new insights to a better understanding of the effects of different exercise treatment strategies on improving knee functions. These systems are specially designed equipment to ensure movement and controlled loading during exercise therapy and, at the same time, to allow a comprehensive assessment of various musculoskeletal conditions (related to the back, spine, neck, shoulder, hip and knee). In combination with the eValuated Exercise platform (EVE software), David systems have the ability to quantitatively assess in real-time changes in muscle strength and range of motion induced in the targeted area, thus facilitating a progressive exercise for the patient and helping the physician for a more correct decision-making regarding treatment planning. Furthermore, these systems allow for the automatic collection and storage of all useful data for tracking and assessing the success of exercise therapy at different post-treatment times.

The effectiveness of exercise therapy based on such intelligent systems has been proven by several studies that reported significant results in treating back conditions. Thus, Anandani et al. [29] in a study conducted out on 235 patients with low back pain showed that significant pain relief, improvement in functional capacity and reduction in disability, measured by the Visual Analogue Scale score for pain, Functional ability and Oswestry score, were recorded after the patients underwent intelligent David systems-based exercise therapy for 6 weeks. Significant improvement in terms of disability (Oswestry Disability index), pain (Visual Analog Scale score), and functional status (Range of Motion) after exercise therapy with David systems were also reported by Langella et. al [30] in a retrospective observational study on 103 patients with low back pain. In a study conducted out on 11 adolescent females with low back pain, Marcu et al. [31] reported a 67% decrease in pain after only 4 weeks of David systems-based exercise therapy. Positive effects of intelligent systems-based exercise therapy were also reported by Chesnikova et al. [32] in the rehabilitation of patients with spondyloarthrosis of the cervical spine.

Although few, all these studies highlighted the effectiveness of intelligent David systems-based exercise therapy in relieving low back pain. To our knowledge, there are currently no studies in the available literature that have reported other medical applications of David systems-based exercise therapy. Therefore, there is a great need for scientific support for the use of this therapeutic methodology not only for back pain, but also for expanding its medical applications.

As response to this need, this paper aims to assess the effectiveness of intelligent David systems-based exercise therapy for different knee conditions in terms of gain in knee mobility and muscle strength in extension and flexion.

This main objective was achieved by addressing the following issues: (a) initial testing of each patient and setting the parameters of an individualized treatment (duration, frequency, intensity of exercise, and nr sessions/week); (b) tracking patients progress during therapy and adjusting treatment parameters; (c) monitoring the effects of intelligent David systems-based exercise therapy in the short-term (immediately after treatment), medium-term (6 months) and long-term (12 months) follow up; and (d) performing the analysis of measured data (knee mobility and muscle strength) and assessing the effectiveness of David systems-based exercise therapy for different knee conditions.

2. Materials and Methods

2.1. Patients

A total of 60 patients (28 men and 32 women), aged between 18 and 84 years (mean age±standard deviation: 53.6±16.38 years), diagnosed with various knee conditions who underwent David systems-based exercise therapy at Eforie Nord Clinical Hospital for Rehabilitation, Physical Medicine and Balneology (EFOSAN) between June 2021 and September 2024 were enrolled in this preliminary observational study (Table 1). Inclusion criteria were: persistent pain refractory to medical treatment, limited knee mobility and/or muscle strength. Exclusion criteria were: acute or decompensated conditions, knee fractures, infection, recent knee surgeries, cancer, cardiopulmonary, or vascular disorders.

Table 1 Demographic data

Characteristics	Values
Number of subjects	60
Age	
Mean (±SD), years	53.6±16.38
Range, years	18-84
Height	
Mean (±SD), cm	170.9±9.31
Range, cm	150-193
Weight	
Mean (±SD), kg	80.8±16.21
Range, kg	45-127
Sex, n (%)	
Male	28 (46.66)
Female	32 (53.33)
Pathology, n (%)	
Osteoarthritis	32 (53.33%)
Knee instability	21 (35%)
Patelofemoral syndrome	7 (11.67%)

Prior to inclusion, informed consent was obtained from all patients and patient data protection was ensured. This study protocol was approved by the Ethics Committee of the Eforie Nord Clinical Hospital for Rehabilitation, Physical Medicine and Balneology. All procedures involving human participants were performed in accordance with the 1964 Helsinki Declaration and its subsequent amendments or comparable ethical standards.

2.2 Intelligent David systems-based exercise therapy (IDET therapy)

IDET therapy based on two David systems (David Health Solutions, Helsinki, Finland), one dedicated to knee extension (model G200 - targeting knee extensor muscles: vastus medialis, vastus lateralis, vastus intermedius, rectus femoris) and the other to knee flexion (model G300 - targeting the flexor muscles: gluteus maximus, biceps femoris, semimembranosus, semitendinosus), was applied in this study to treat patients with knee conditions. IDET therapy consisted of three steps (Fig. 1.a).

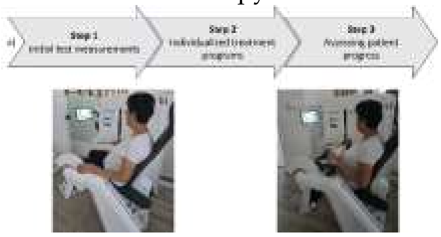

Fig. 1 Flowchart showing the steps of IDET therapy and patient positioning in David systems. a) steps of IDET therapy; b) patient positioning in the G200 knee extension system; c) patient positioning in the G300 knee flexion system

In the first step, each patient, seated in a correct posture on each of the two David medical systems (Fig. 1.b and 1.c), underwent initial test measurements to set the input values of knee mobility (in extension and flexion) and isometric muscle strength (in extension and flexion) at baseline (T0) and generate individualized treatment program on each system using EVE software.

The individualized treatment programs thus created included for each patient their own set of treatment parameters: type of exercise (e.g. knee extension or knee flexion), range of motion (knee extension: 0°- 80°; knee flexion: 0°- 115°), speed of exercise (10 degrees/second), number of repetitions (15-20 repetitions on each David system, every session), duration (60 – 80 s /each David system), number of sessions (10 sessions/each David system, spread over 2 weeks). In the second step of IDET therapy all patients underwent these individualized treatment programs for a minimum period of 2 weeks. Throughout this period, treatment parameters were adjusted by the physician according to the needs and progress of each patient. The progress recorded by patients at the end of the treatment period (T1), as well as in the medium term (6 months, T2) and long term (12 months, T3) follow up were assessed in the third stage, based on the parameters stored and reported by the EVE software. At 6 months, after T2 evaluation, all patients received a second IDET two-week session.

2.3 Statistical Analysis

The results were expressed as mean ± standard deviation. The normality of the data was checked with the Shapiro-Wilk test. Data were compared using Paired Samples t - Test. A significance level of $p < 0.05$ was considered for statistical significance. The statistical analysis was performed using SPSS software v23 (International Business Machines Corporation (IBM), New York, United States).

3. Results

Figure 2 shows the scatter plots of the input values of knee mobility in extension (M_{ext}) and flexion (M_{flex}) as well as the isometric muscle strength in extension (S_{ext}) and flexion (S_{flex}) at baseline (T0) as a function of the age of the patients.

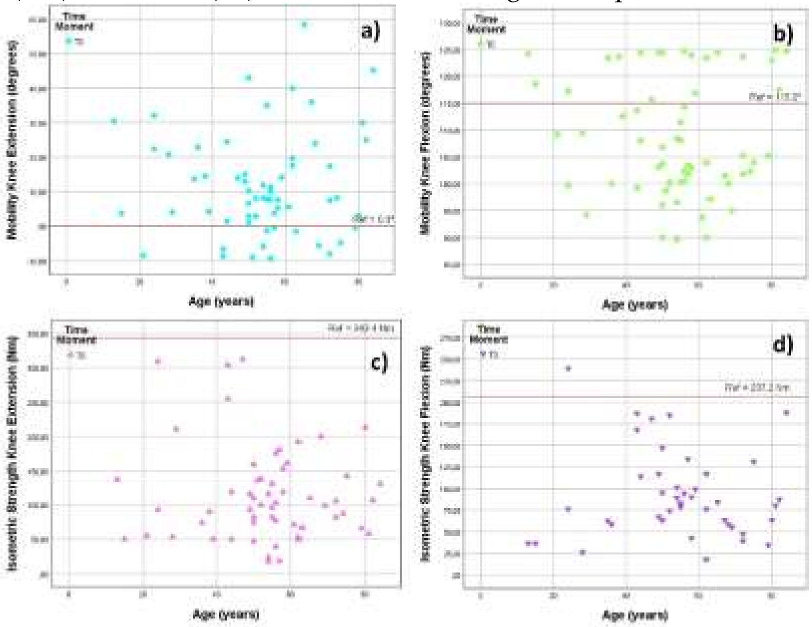

Fig. 2 Scatter plots of the input values of knee mobility in extension and flexion and isometric muscle strength in extension and flexion at baseline (T0) as a function of the age of the patients. a) scatter plot of the input values of mobility knee in extension; b) scatter plot of the input values of mobility knee in flexion; c) scatter plots of the input values of isometric strength knee in extension; d) scatter plot of the input values of isometric strength knee in flexion

Figure 2 shows that, at T0 (before IDET therapy), all patients (irrespective of their diagnosis or age) had major knee function limitations the parameters' values being widely scattered compared to reference values. It is worth noting in Fig. 2a that values for knee mobility in extension were between -9.20° and +58.40° (Table 2), with 21.66% of the patients showing negative values and the rest (78.33%) showing positive values. The values for knee mobility in flexion were between 89.90° and 124.90°, 31.66% of the patients displaying higher values than the reference (115°) (Fig. 2b). All patients showed lower than normal (343.4 Nm for extension and 207.2 Nm for flexion) isometric flexion and extension strengths. There was only one exception, a young man (24 years old) who had a higher-than-normal isometric flexion strength (239.00 Nm) (Figs. 2c and 2d).

Table 2. Input values of mobility and isometric muscle strength in knee extension and flexion for all patients at baseline (T0)

Parameters	No. patients	Minimum	Maximum	Mean	Std. Deviation
Mobility Knee Extension (degrees)	60	-9,20	58,40	11,7017	14,90594
Mobility Knee Flexion (degrees)		89,90	124,90	107,9500	11,19585
Isometric Strength Knee Extension (nm)		18,00	312,00	114,8070	69,05806
Isometric Strength Knee Flexion (Nm)		18,00	239,00	91,0652	49,02761

After applying the individualized IDET therapy program for two weeks (10 sessions), the patients' response to treatment was different, as evidenced by positive or negative changes in the values of the input parameters. As an example, the evolution of the first 15 patients in the study group is presented in Figure 3.

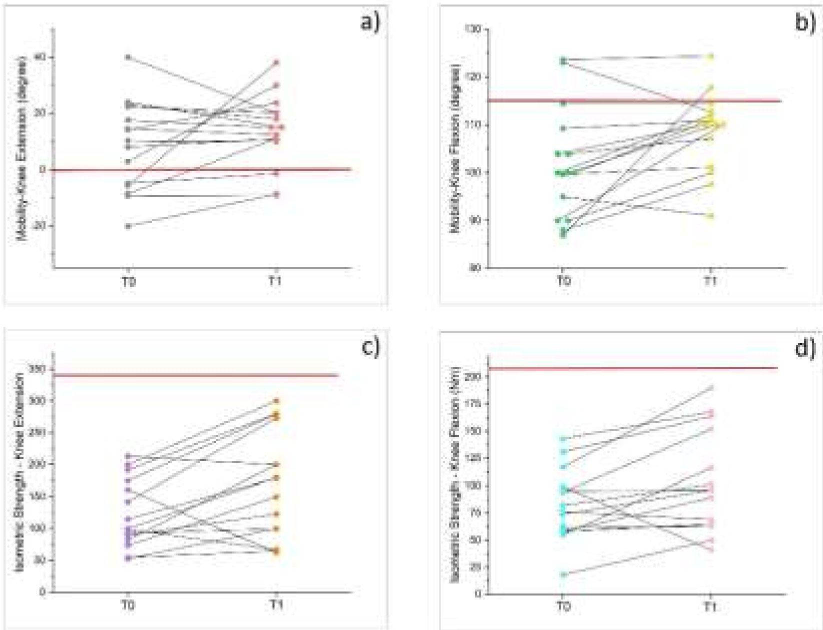

Fig. 3 The evolution of the first 15 patients in the study group at the end of IDET therapy: a) knee mobility in extension; b) knee mobility in flexion; c) isometric strength knee in extension; d) isometric strength knee in flexion

In Figure 3, it is noteworthy that the general trend of change in mobility and isometric strength in both knee extension and flexion is towards the reference values, with some exceptions (Table3).

Table 3. IDET therapy-induced gain in knee mobility and muscle strength for the first 15 patients

Pa-tient	Mobility				Strenght			
	Extension		Flexion		Extension		Flexion	
	$\Delta M_{ext\ (T1-T0)}$	Gain (%)	$\Delta M_{flex\ (T1-T0)}$	Gain (%)	$\Delta S_{ext(T1-T0)}$	Gain (%)	$\Delta S_{flex(T1-T0)}$	Gain (%)
1	-2.2	-2.442	1.5	1.305	7.0	2.030	-7.0	-1.172
2	19.5	21.645	1.6	1.392	10.0	2.900	2.0	10.389
3	0.3	0.333	0	0	104.0	30.160	58.0	0.159
4	3.4	3.774	3.2	2.784	131.0	37.990	33.0	1.811
5	-2.1	-2.331	0.8	0.696	33.0	9.570	19,2	-1.119
6	-20.0	-22.200	10.0	8.700	88.0	25.520	73.0	-10.656
7	27.0	29.970	-10.3	-8.961	-13.0	-3.770	0	14.386
8	-9.0	-9.990	10.0	8.700	100.0	29.000	7.0	-4.795
9	-2.6	-2.886	6.1	5.307	47.0	13.630	32.0	-1.385
10	-0.3	-0.333	20.0	17.400	118.0	34.220	1.0	-0.159
11	43.6	48.396	-4.0	-3.480	-32.0	-9.280	61.4	23.230
12	9.5	10.545	30.9	26.883	-98.0	-28.420	-58.0	5.062
13	11.4	1.654	9.6	8.352	64.0	18.560	25.0	6.074
14	-4.9	-5.439	12.0	10.44	76.0	22.040	31.0	-2.611
15	3.0	3.330	10.0	8.700	80.0	23.200	22.0	1.598

The small improvement or lack of improvement observed in some patients was probably caused by age and advanced age-related degenerative changes of the joint. However, an increase in the mean values of knee mobility and muscle strength in both extension and flexion were recorded after two weeks of IDET therapy. Change in knee mobility in extension compared to baseline value was ΔM_{ext}= 5.11°±15.541°, representing a mean gain of 4.94°±17.165%. Knee flexion mobility improved more, with the mean value increasing by ΔM_{ext}= 6.76°±9.931° (mean gain of 5.88°±8.639%). Muscle strength values also recorded increases, more important in knee extension (ΔS_{ext}=

47.67±63.291Nm, mean gain = 13.83±18.354 %) than in knee flexion (ΔS_{flex}= 19.97±32,179 Nm, mean gain = 2.721±8.279%).

When the whole study group (60 patients) was taken into account, statistically significant variations were recorded for the investigated parameters (Figure 4).

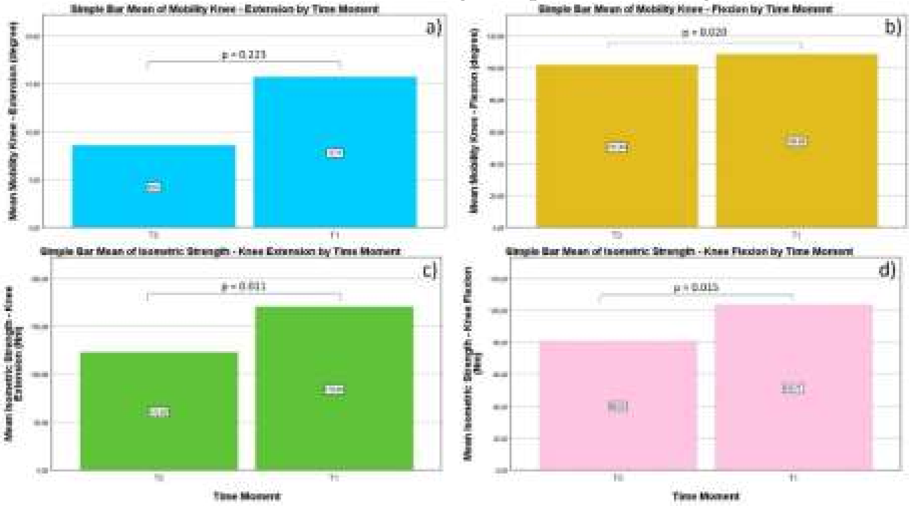

Fig. 4 The effectiveness of IDET therapy in improving knee mobility and muscle strength at short term follow up. a) knee mobility in extension variation; b) knee mobility in flexion variation; c) muscle strength in extension variation; d) muscle strength in flexion variation

The mean value of knee mobility in flexion increased after IDET therapy (at T1) with ΔM_{flex} = 6.76°±2.563° (mean gain = 5.88%) (paired-samples t test: t_{59} = 2.637, p = 0.020). Mean muscle strength in extension also increased with ΔS_{ext} = 47.07±16.341 Nm (mean gain = 13.65%) (paired-samples t test: t_{59} = 2.917, p = 0.011). Mean muscle strength in flexion also increased with ΔS_{flex} = 22.77±8.256 (mean gain = 10.93%) Nm (paired-samples t test: t_{59} = 2.758, p = 0.015). On the other hand, the mean value of knee mobility in extension also increased, but its variations were statistically nonsignificant (ΔM_{flex} = 7.10°±5.576°, paired-samples t test: t_{59} = 1.274, p = 0.223). All these results are statistically significant, demonstrating the effectiveness of IDET therapy in improving muscle strength in both extension and flexion and knee mobility in flexion at short-term follow up, but knee mobility in extension was not improved statistically significant.

Improvements in knee parameters were also recorded at medium-term (6 months – T2) follow up and long-term (12 months-T3) follow up as displayed in Figure 5.

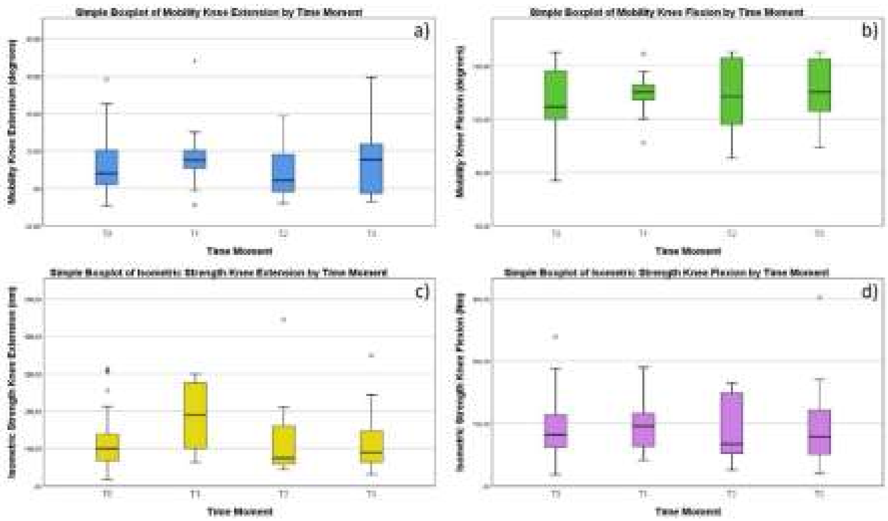

Fig. 5 Box plot showing changes in knee mobility and muscle strength at different time points after IDET therapy. a) variations in knee mobility in extension; b) variations in knee mobility in flexion; c) variations of isometric strength in extension; d) variations of isometric strength in flexion

As can be seen in Figure 5a the distribution of M_{ext} values for patients in the study group varied in time from -9.20° to 8.40° (mean = 11.70°±1.924°) at baseline (T0), -8.90° to 36.10° (mean = 15.31°±3.139°) at T1 (at the end of therapy, short-term follow up), -7.90° to 38.70° (mean = 8.97±3.517°) at T2 (6 months – medium-term follow up), and -7.10° to 59.70° (mean = 14.75±3.427°) at T3 (12 months - long-term follow up), respectively. The immediate effect of IDET is obvious with average values raise of ΔM_{ext} = 3.61°±1.021° (gain = 4.01%) (Table 4).

Table 4. Gain in knee mobility and muscle strength at different time moments of IDET therapy

Parameters	**Gain at different time moments vs baseline (%)**		
	T1	**T2**	**T3**
Mobility Knee Extension (degrees)	4.01	-3.03	3.39
Mobility Knee Flexion (degrees)	1.25	0.51	2.77
Isometric Strength Knee Extension (nm)	16.01	2.57	-1.08
Isometric Strength Knee Flexion (Nm)	3.86	-0.30	1.41

At T2, we registered a regression of the average values of ΔM_{ext} = -2.73°±1.043° (gain = -3.03%). Nevertheless, at T3, an important improvement was noted ΔM_{ext} = 3.05°±1.105° (gain = 3.39%). This shows the benefic effect of the therapy on knee mobility in extension, even though, immediately after the therapy, the improvement was not statistically significant. Before the therapy, M_{ext} showed an asymmetrical distribution, with the median in the inferior part of the box plot (lower values of M_{ext} are more widespread than higher values), while immediately after the therapy the distribution became more symmetrical with the median located approximately in the middle of the box plot, proving that the therapy tends to level the values of the parameter. At T2 and T3, the variability among the patients became again high, with box plot asymmetries. The variability of M_{ext}, measured by the interquartile interval (IQR), was: 18.75, 10.33, 21.60, and 27.60, respectively. The highest variability was noted at T3. It should also be noted that the box plots at T0, T2 and T3 are not centered between the whiskers, which means that at these times many low values of M_{ext} were recorded and only a few extremely high ones. Overall, the distribution of M_{ext} values at different time points of therapy appears to be generally asymmetric, with particular variability post-treatment, but there is a clear progress of patients regarding knee extension mobility after 12 months of IDET therapy. The gain is, however, relatively small, the values remaining far from the reference values (M_{ext} = 0°). This could be explained by different evolutions of the knee conditions (with osteoarthritis probably worsening), which can also be linked to the variability of the patients' efforts to maintain the gains in mobility during the post-therapy period. Overall, the impact of the IDET therapy on this parameter was good, but the improvement was somewhat small.

A similar evolution was observed for knee mobility in flexion (Fig. 5b). The mean values raised immediately after IDET with ΔM_{flex} = 1.44°±1.024° (gain = 1.25%) above the baseline, then a slight decrease was detected (ΔM_{flex} = -0.09°±0.005° compared to T1), but still above the baseline and, finally, a new raise was recorded at T3: ΔM_{flex} = 2.61°±1.321° (gain = 2.77% vs baseline). An asymmetry of the distribution of M_{flex} values at T0, T2 and T3 is also detectable, with lower values more grouped than higher ones (with median values at 104.55°, 108.40° and 110.00° respectively). Immediately after IDET (T1), the recorded values are symmetrical, with the median localized close to the center of the box plot (110.00°) showing that the therapy was successful in leveling the performance of knee flexion for all the subjects. The highest variability was again recorded at T2 (IQR = 27.10) when some of the gain was lost. The second IDET session at

6 months might be the cause for the improvement noted at T3. The box plot is not centered between the whiskers for this parameter also, but the high values are predominant. Despite a great variability of the data, a gain was recorded proving IDET therapy to be effective in improving knee flexion.

Muscular strength in extension (S_{ext}, Fig. 5c) had low values before therapy (mean = 114.81±9.147 Nm) compared to the reference value (344.7Nm), with a symmetrical distribution of the data, the median being close to the center of the box (median = 100.00 Nm), and with a low data variability (IQR = 73.50). After the therapy, the distribution of the values remains symmetrical (median at 165 Nm), and an important raise was recorded (ΔS_{ext} = 55.19±2.917 Nm with a gain of 16.01%), but with important data variability (IQR=182.75), demonstrating big differences in patient' response to IDET therapy. The gain in S_{ext} decreased considerably at mid-term follow up (T2) (ΔS_{ext} = -46.33±3.541Nm; gain = 2.57% vs baseline). Data distribution becomes asymmetrical (median = 74.00 Nm; data range (42.00-444.00) Nm), with most of the values situated in the lower half of the box plot. Most of the patients showed a significant regress, data variability being low (IQR=111.00Nm), with a predominance of lower values leading to an asymmetrical data distribution. The regressive trend was maintained at T3 (ΔS_{ext} = -12.57±2.843 Nm vs T2, and gain = -1.08% vs baseline). Most of the patients are clustered in the lower part of the box plot (median=89 Nm) with only few exceptions maintaining their gain in muscular strength. On the long term, the response of this parameter was negative.

On the other hand, mean values of isometric strength knee flexion measured before and after therapy (T0, T1, T2, and T3) were: 91.07±7.229 Nm, 99.11±11.721 Nm, 90.44±17.524 Nm, and 94.00±11.367 Nm, respectively. All these values are lower than reference ($S_{flex-ref}$ = 208.4 Nm) (Fig. 5.d). Their distribution at any of the investigated moments was asymmetrical showing the high diversity of the patients' limitations, of their response to therapy, and of their evolution in time. At T1, most of the patients had low values of the parameter, clustered in the lower part of the box plot (median = 81.00 Nm), but, after IDET, the median raised (96.00 Nm) and the values clustered in the upper part of the box plot, showing a good response to therapy (a gain of 3.86%). At T2 (6 months after therapy), the effect of IDET therapy slightly diminished vs baseline: a decrease of the mean (67.00 Nm, gain = -0.30% vs. baseline), with most of the patients clustered near the inferior line of the box plot. At long term follow up (T3) the isometric strength of knee flexion improved (mean = 79 Nm, gain = 1.41% vs. baseline), with values evenly distributed in the box plot. The variability of S_{flex} values at different time moments (interquartile interval) were: 56.75, 63.30, 101.50, and 84.00 respectively. This proved the high heterogeneity of the group in terms of response to therapy generated by differences in pathologies and their evolution and also in personal motivation to maintain or even improve the gains recorded immediately after IDET therapy.

IDET therapy produced improvements of all parameters at the end of therapy, with mobility (both in extension and flexion) maintaining part of the gain at long term follow up. Mobility in flexion showed the best improvement at any moment. A decrease of all parameters was noted at 6 months (T2), but mobility recovered partially. As stated early, this may be explained by a temporary inflammation of the joint, probable associated with pain, or a difficulty in adaptation of the life style to improved parameters which was overcome progressively toward the end of the follow up period. Muscle strength, although improved initially, was more difficult to maintain. While mobility can be maintained with passive exercises, muscle strength needs sustained physical activity, a requirement that many patients could not meet.

4. Discussion

Herein we report on the study conducted to analyze the effectiveness of intelligent systems-based exercise therapy as a treatment option for the different knee conditions including osteoarthritis, knee instability and patellofemoral syndrome. Different treatment options are recommended for these knee conditions depending on the cause and severity of the condition, either conservative (rest, ice application, compression and elevation of the leg (R.I.C.E.), physical therapy and use of braces) combined with pain relief medications or surgical correction [33]. Beside these treatment approaches, many other treatment options were proposed, including the intelligent David systems-based exercise therapy. Unfortunately, to date, only a few studies have focused on the use of this therapy and only on low back pain [29–32], but their results are encouraging.

In this study the effectiveness of IDET therapy for three knee conditions was quantitatively assesses, for the first time to our knowledge, based on the analysis of gain in knee mobility and muscle strength in extension and flexion. With this aim, the effects of IDET therapy were monitored in the short term, medium (6 months) and long term (12 months) and the changes in mobility and muscle strength values in both extension and flexion at different time points were compared.

The results presented here showed that all the recorded parameters improved immediately after IDET therapy, demonstrating that this type of therapy was able to increase knee function, both in terms of range of motion (mobility) and muscular strength. It is true that knee extension gain was somewhat small, and its true clinical value is debatable. We believe (but this assertion needs further testing and clinical confirmation) that younger, motivated patients are the ones who would profit the most from IDET therapy, because post IDET exercises are needed to maintain and improve the gains (vide infra).

The short-term results (immediately after IDET therapy) are in agreement with the results previously reported by Anandani et al. [29] regarding the effectiveness of device-based exercise therapy in the management of low back pain, but also with those reported by Chesnikova et al. [32] who highlighted the potential of this therapeutic modality for the rehabilitation of patients with cervical spondyloarthrosis. Medium- and long-term patients' evolution after IDET is for the first time presented in a study. All the mobility parameters demonstrated a decrease at 6 months with a regain at 12 months. Further research is needed in order to explain such a behavior, with detailed analysis of the patient condition. It was clear though, that muscle strength diminished at 6 and 12 months, probably due to a lack of an exercise program aimed at conserving the gains produced by the IDET therapy. Repeating the IDET therapy in the first year, as well as modifying the training parameters at each repetition according to the parameter evolution might be another good solution for preventing muscle strength loss. The causes of the gain loss with time should be thoroughly investigated through a deeper analysis of the disease's evolution at mid- and long-term.

Overall, the study results suggest that IDET therapy was able to improve both extension and flexion knee mobility even at 12 months, but muscle strength around the knee joint was improved only temporarily.

The gain in muscle strength could have been preserved or even improved with a rigorous post-IDET physical therapy program, ideally one that the patient could adhere to at home. Patients' adherence to the IDET program was very good (therapy was performed in the hospital, hospitalization in the center being a condition for their participation in the program), but data on their adherence to the recommended home exercises were not collected. Yet, this new kinesitherapy approach prove as a good way of improving overall knee function in all the investigated conditions. It is a personalized method, based on specific parameter evaluation of the disease and it allows for an objective assessment of the progress of the knee function. However, even though these results demonstrated the potential of IDET therapy to improve knee function, future combination with other clinical scales, such as WOMAC, KOOS or VAS, is needed to strengthen them.

However, the study has some limitations. Firstly, small number of patients. Secondly, the response to IDET therapy by gender and age could not be analyzed, also due to the small number of patients selected for this study. In addition, although we were able to highlight the immediately significant effect of IDET therapy in the three knee conditions, we were unable to determine the cause of the regression in the medium-term due to the lack of periodic clinical investigations Furthermore, validation of the results on a larger number of patients is required. Moreover, we could not provide a thorough analysis on each of the three pathologies investigated, the study being less specific. More subgroup analysis (gender, age) could have been useful, but the limited dimensions of the group would have generated even smaller subgroups with even lower statistical power of the results. Some of the results might be influenced by the natural course of the illnesses which is a major limitation. Lack of a control group is another major limitation, but this can only be solved in the future, where classical physical therapy (control group) could be compared with IDET therapy. Comparison with a retrospective classical therapy group is inappropriate at this time and it would probably generate unreliable conclusions. However, the present study has made a pioneering contribution to future research on the effectiveness of IDET therapy in knee conditions and all the above limitations will be addressed in the further studies.

All these limitations should be addressed in future research: selecting a larger group of patients, designing a control group (by direct matching or, better, by randomization) that would benefit from classical physical therapy, more specifical analysis for each knee condition (by selecting less heterogenous study groups), and taking into account the clinical outcome in terms of pain, mobility and quality of life (by employing a validated clinical questionnaire). Multicentric studies should be performed, so that the conclusions are more accurate and the method gains general applicability.

Conclusion

In conclusion, the value of the David system – based exercise therapy in improving knee function in patients suffering from knee osteoarthritis, knee instability and patellofemoral syndrome was observed on short term. The method improved all the investigated parameters of the knee function (at least temporarily when referring to muscle strength). However, its effectiveness over a large period of time is debatable and larger and more targeted studies are necessary in order to draw undisputable conclusions. Prospective randomized controlled studies with longer follow up and directed more specifically to each knee disfunction are needed in order to demonstrate the value of the method.

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