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Relationships between balance control and cognitive functions, gait speed, and activities of daily living

Introduction

Mild cognitive impairment (MCI) is widely regarded as a transitional syndrome between normal cognitive aging and clinical dementia. Older adults with mild cognitive impairment demonstrate decreased cognitive function and balance performance. Abnormalities in balance and postural control are common in elderly people with MCI. Postural control in everyday life is generally accompanied by posture-unrelated cognitive activity. Maintaining and improving balance function may be beneficial for preventing progression to Alzheimer's disease in older adults with MCI [18].

Better understanding is needed of the modifiable factors independently associated with improved balance control. This would ensure effective intervention based on a valid theoretical framework for improving balance control. Possible modifiable factors include cognitive function and gait speed with and without a dual cognitive task [18].

Several cross-sectional studies support the hypothesis that cognitive and physical function are interrelated in people with MCI [18]. McGough [10] examined associations between physical performance and executive function together with gait speed in older adults with MCI, and Tangen [17] examined relationships between balance and cognition in patients with MCI. Jakubovski [7] examined interplay between gait, fall risk, and cognition.

In a systematic review, Pichierri [13] pointed out the need to examine the relationship between improvements in cognitive skills and better performance in physical tasks, balance performance, and activities of daily living, after completing various kinds of cognitive and physical training.

The purpose of this study was to examine the above associations by seeking correlations between balance control and cognitive functions at baseline and after 10 weeks of training, using a cognitive—motor intervention in older adults with MCI. Other factors including gait speed and activities of daily living were also investigated.

Methods

The study sample consisted of patients who had mild cognitive impairment, confirmed by their psychiatrist and psychologist and based on a standard clinical examination and neuropsychological testing, in line with the criteria defined in the ICD-9-CM 331.83 [1, 11].

The study was performed in the outpatient psychiatric clinic of the highly specialized Geriatric Institute of St. Lukas in Košice, Slovak Republic, where elderly patients from the region are referred for diagnosis and treatment. A total of 100 patients were recruited for the study between June 2013 and March 2014 (**Fig. 1**).

Inclusion criteria. Mild cognitive impairment, encompassing subjecti ve mild decrease in memory, and attention domains. Age over 65 years but less than 75.

Exclusion criteria. Moderate and severe cognitive deficits of MMSE ≤ 23, major depressive and anxiety disorder, cancer, significant visual and auditory damage, prior history of neurological disease or brain injury, and psychiatric disorders.

Out of 100 patients, 5 patients were excluded due to the symptoms of severe depression; 15 patients declined to participate; 80 patients were enrolled into the study by one member of the research team who was not involved in the assessment and did not conduct the interventions. The baseline sample consisted of 80 patients randomly divided into groups with 1:1 allocation.

The project's data analyst generated a random sequence of numbers to arbitrarily select probands for the experimental group and the control group using Microsoft Office Excel 2010 computer program. These numbers were put in a subsequently sealed envelope. The project manager opened the envelope and informed the participating persons of their assignment to one of the two groups.

Data collection consisted of two measurements: one taken at baseline and another after 10 weeks. The persons who participated in the data collection did not participate in the implementation of the training programs. The patients were informed that there were two kinds of training, but they were not told what kind of intervention they would undergo and what the expected results were. The training staff was not blinded.

In the experimental group, all included persons completed the program. In the control group, two individuals did not complete the training program due to respiratory disease. All included pro-

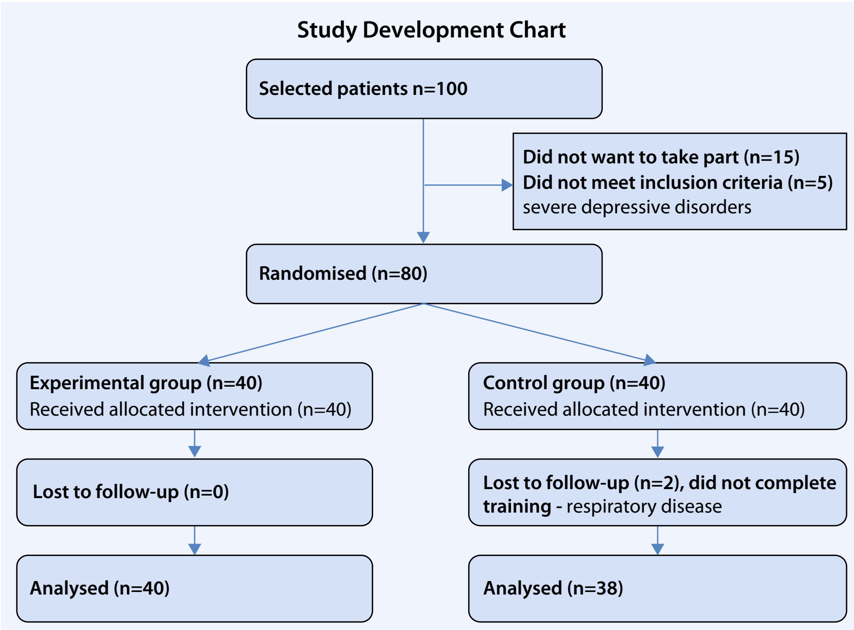

Fig. 1 ▲ Study development chart

bands signed the informed consent form. The study protocol was approved by the local ethics committee of the highly specialized Geriatric Institute of St. Lukas in Košice, Slovakia.

Cognitive training battery

The cognitive training was conducted using a battery of tests from the CogniPlus training program from SHUFRIED GmbH Company in Austria [4]. CogniPlus is a training program with a scientific background. The training programs are with recommendation strength A in the guidelines of the Society for Neuropsychology, 2009. The training battery contains subprograms for attention training, working memory, long-term memory, executive functions, visuomotor coordination, and spatial processing, among others.

Our training battery was specially developed and designed for patients with mild cognitive deficit and comprised the following subprograms:

Attention intensity (“*Alert*”) the training was performed by means of driving a virtual car. Each of the two training forms contains 18 difficulty levels.

Long-term memory (“*Names*”) has 17 difficulty levels. The probands were asked to remember names and surnames in connection with faces.

Executive functions (“*Pland*”) the S1 training form has 19 difficulty levels, the S2 form has 16 and the S3, 28. In all training forms, the number of actions required increases as the difficulty level rises.

Working memory (“*Nback*”) has 15 difficulty levels. Participants were shown pictures of, for example, animals, people, and countries, and were then asked to remember two or three pictures previously presented.

Visual–motor coordination (“*Vismo*”) has 22 difficulty levels. Participants followed a spaceship on the screen and were asked to keep it inside a circle.

The aim of the training was to gradually achieve the maximum level of performance in different types of training. The exercises alert, names, and pland 1, 2 were quickly mastered up to the maximum level of difficulty. For this reason, we decided to combine them with motor exercises into a dual task as follows: the participant stood and changed his/her position from the left foot to the right, and then stood on his/her toes; stood up and sat down on the chair; and stepped forward or backward, to the left or to the right.

Each training session lasted 30 min; each type of subprogram took 10 min. During 1 week, all of the cognitive functions were covered in the training. Each participant attended 10 training sessions twice a week, a total of 20 sessions.

Motor training

Both groups underwent 30 min of motor training daily for 10 weeks, in accordance with instructions given by a physiotherapist. The training contained the following exercises:

Walking over obstacles. Participants walked over five boxes, then turned and walked back.

Walking with direction and speed changes. Participants walked 10 m and then turned back, increasing their pace, and then slowed.

Walking with a load. Participants walked while carrying a load in one hand, and then in both hands.

Walking up and down stairs. Participants walked up and down ten steps [12].

Outcome measures

Global cognitive status was assessed using the Mini Mental State Examination (MMSE), which was used for descriptive purposes but not in the analysis. This is a method used for screening basic cognitive functions [5].

Balance

BESTest (Balance Evaluation Systems Test) [6].

The maximum score totals 108 points, indicating that the participant has no problems with balance. It consists of six sections: biomechanical limits (maximum 15 points); stability limitation in vertical (maximum 21 points); anticipatory postural adjustment (maximum 18 this points); postural reactions (maximum 18 points); sensory orientation (maximum 15 points); and walking stability (maximum 21 points). We included only the total score in the analysis.

Cognitive functions

Trail Making Test (TMT), Form A [2, 13]. This tests attention, psychomotor speed, and the ability of visual search. Version A contains 25 numerals. The participant is asked to combine numerals from 1 to 2 up

to numeral 25 as quickly as possible. The time in seconds and the number of errors were rated.

The Nine Hole Peg Test [7] measures psychomotor coordination and the fine motor functioning of the dominant hand. Assessment concerned the time in seconds and the number of errors when inserting pins into the holes.

Gait speed with and without dual task

The Timed Up and Go Test (TUG) [16] measure dynamic balance. While sitting in an armchair, at the signal the participant stands up, walks 3 m, walks back, and sits down with maximal speed. The mean time of three trials was measured in seconds.

TUG DT with dual tasking: the test was performed as above with the addition of a dual cognitive task; participants were asked to continuously subtract the digit 3 from 100 [16].

Activities of daily living

Bristol Activities of Daily Living Scale (Badl-s-cz) contains 20 questions [3, 15]. This scale is designed to measure the ability to perform everyday activities in people with mild to advanced dementia. It evaluates the ability to carry out tasks related to preparing meals and drinks, dressing, hygiene, toilet, mobility, orientation, communication, housework, shopping, and social life. The lower the score, the better the result.

Statistical analysis

For the data analysis, descriptive and bivariate statistics were used. The non-paired t-test and χ^2 test were used to compare variables in the experimental and control groups before the training. The pre-condition for the calculation of t-tests and correlations is the verification of normal distribution by the Shapiro–Wilk test and the D' Agostino–Pearson test. The degrees of relationships between variables (e.g., the strength of correlations at baseline and after intervention) were investigated using Pearson's r. Score (point) values of the correlation coefficient r were

Abstract · Zusammenfassung

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Relationships between balance control and cognitive functions, gait speed, and activities of daily living

Abstract

Purpose. The purpose of this study was to examine the relationship between balance control and cognitive functions, gait speed, and activities of daily living.
Sample. In all, 80 elderly participants with mild cognitive impairment (mean age 67.07 ± 4.3 years) were randomly allocated into the experimental group ($n = 40$) or the control group ($n = 40$).
Methods. Balance control was evaluated by the Balance Evaluation Systems Test (BESTest). Cognitive functions were evaluated by the Trail Making Test and the Nine Hole Peg Test. Gait speed was assessed by the Up and Go test with and without dual task. For evaluation of activities of daily living (ADL), the BADLS test was used. The experimental group underwent CogniPlus 20 training sessions twice a week. Both groups had 30 min of physical training daily for 10 weeks.
Results. After training, there were five significant correlations found in the experimental group (balance control and visuomotor coordination, psychomotor speed, gait speed with and without cognitive tasks, and activities of daily living). In the control group, one significant correlation was found between balance control and gait speed.
Conclusion. The cognitive-motor training performed for 10 weeks confirmed more significant relationships between balance control, cognitive functions, gait speed, and activities of daily living, when compared with motor intervention alone.

Keywords

Balance · Cognitive · Gait · Activities of daily living

Beziehung zwischen der Kontrolle des Körpergleichgewichts und kognitiven Funktionen, Gehgeschwindigkeit sowie Aktivitäten des täglichen Lebens

Zusammenfassung

Zielsetzung. Ziel dieser Studie war es, die Beziehung zwischen der Kontrolle des Körpergleichgewichts und den kognitiven Funktionen, der Gehgeschwindigkeit sowie den Aktivitäten des täglichen Lebens zu untersuchen.
Stichprobe. Insgesamt 80 ältere Menschen mit leichter kognitiver Beeinträchtigung (Durchschnittsalter 67,07 ± 4,3 Jahre) wurden randomisiert und der Versuchsgruppe ($n = 40$) oder Kontrollgruppe ($n = 40$) zugeteilt.
Methoden. Die Kontrolle des Körpergleichgewichts wurde mit dem Balance Evaluation Systems Test (BESTest) bewertet. Kognitive Funktionen wurden mit dem Trail Making Test und dem Nine Hole Peg Test eingeschätzt. Die Gehgeschwindigkeit wurde im Timed-Up-and-Go-Test mit oder ohne doppelte Aufgabenstellung ermittelt. Für die Bewertung der Aktivitäten des täglichen Lebens wurde der BADLS-Test angewendet. Die Versuchsgruppe durchlief 2-mal wöchentlich CogniPlus-20-Trainingseinheiten. Beide Gruppen absolvierten über 10 Wochen täglich ein 30-minütiges körperliches Training.
Ergebnisse. Nach Beendigung des Trainings wurden 5 signifikante Korrelationen in der Versuchsgruppe festgestellt (Kontrolle des Körpergleichgewichts und visuomotorische Koordination, psychomotorische Geschwindigkeit, Gehgeschwindigkeit mit und ohne kognitive Aufgaben sowie Aktivitäten des täglichen Lebens). In der Kontrollgruppe fand sich nur eine signifikante Korrelation zwischen der Kontrolle des Körpergleichgewichts und der Gehgeschwindigkeit.
Schlussfolgerung. Das kognitiv-motorische Training über 10 Wochen bestätigte im Vergleich zur alleinigen motorischen Intervention mehr signifikante Beziehungen zwischen der Kontrolle des Körpergleichgewichts und den kognitiven Funktionen, der Gehgeschwindigkeit und den Aktivitäten des täglichen Lebens.

Schlüsselwörter

Körpergleichgewicht · Kognition · Gang · Aktivitäten des täglichen Lebens

Table 1 Demographic and baseline characteristics of study participants

Sample characteristic ($n=80$)	Experimental group $n=40$/% mean ± SD	Control group $n=40$/% mean ± SD	t-test/ Chi-square test[a]	p
Age	68.2 ± 6.7	65.7 ± 5.6	1.825	0.07
Gender Male/female	22/18 (55 %/45 %)	19/21 (48 %/52 %)	0.45[a]	NS
Education secondary/college	1.25 ± 0.43 (77 %/25 %)	1.38 ± 0.49 (70 %/30 %)	−1.202	0.233
Mini Mental State Examination (MMSE)	25.97 ± 2.57	26.03 ± 1.47	−0.106	0.915
Duration of mild mental ailments (months)	16.98 ± 7.37	17.45 ± 6.38	−0.308	0.759

[a]Data are presented as means and standard deviation. ***P***-value based on the independent t-test and Chi-squared test.

Table 2 Correlations between balance control and cognitive functions, gait speed, and activities of daily living in the experimental and control groups before training

Correlation number	Type of correlation	r^e	p	95 % CI		r^c	p	95 % CI	
				Upper	Lower			Upper	Lower
1	BEST/nine hole peg test (t)	−0.08	0.60	−0.38	0.22	−0.13	0.39	−0.49	0.22
2	BEST/TMT test (t)	−0.17	0.28	−0.49	0.17	−0.17	0.29	−0.48	0.13
3	BEST/Up and GO (t)	−0.21	0.19	−0.47	0.13	0.20	0.20	−0.14	0.48
4	BEST/Up and GO -DT(t)	−0.16	0.29	−0.46	0.15	−0.15	0.33	−0.42	0.13
5	BEST/BADLS	−0.25	0.10	−0.55	0.09	−0.16	0.35	−0.46	−0.15

BEST total score of BESTest, ***T*** dual task, ***r***[e-] Spearman correlation coeficient in experimental group, ***r***[c-] Spearman correlation coeficient in control group, ***t*** time in second.

Table 3 Correlations between balance control and cognitive functions, gait speed, and activities of daily living in the experimental and control groups after training

Corelation number	Type of correlation	r^e	p	95 % CI		r^c	P	95 % CI	
				Upper	Lower			Upper	Lower
1	BEST/Nine Hole Peg Test (t)	−0.46	0.002	−0.67	−0.17	0.10	0.54	−0.22	0.40
2	BEST/TMT test (t)	−0.40	0.05	−0.67	−0.15	−0.45	0.004	−0.57	−0.15
3	BEST/Up and GO (t)	−0.37	0.01	−0.61	−0.06	−0.52	0.0007	−0.72	−0.25
4	BEST/Up and GO -DT(t)	−0.47	0.002	−0.68	−0.19	0.31	0.06	−0.05	0.57
5	BEST/BADLS	−0.53	0.0004	−0.72	−0.27	−0.34	0.03	−0.59	−0.02

BEST total score of BESTest, ***T*** dual task, ***r***[e] Spearman correlation coeficient in experimental group, ***r***[c] Spearman correlation coeficient in control group, ***t*** time in second.

supplemented with 95 % reliability (confidence) intervals. Calculations were performed using IBM SPSS 22 software.

Results

Baseline sociodemographic and clinical data were obtained from participants' records. Baseline measures of the common demographic variables of age, gender, education, intelligence, and the duration of mild mental ailments, and all tests, were similar in both groups. The MMSE confirmed mild cognitive impairment (with a mild decrease in the memory and the attention domains). The sociodemographic and clinical characteristics are summarized in **Tab. 1, 2 and 3**).

There were no significant correlations between the groups before training. After the training, the following correlations were found.

We correlated the overall score of the BESTest with visuomotor coordination evaluated by time in seconds in the Nine Hole Peg Test. In the experimental group a significant negative correlation ($p < 0.002$) was found; there was no significant correlation in the control group. (Note: improvement of visuomotor coordination is characterized by shortening of the reaction time in the given test).

The overall score of the BEST-test was correlated with the psychomotor speed evaluated by the reaction time in seconds in the TMT test-A. In the experimental group a significant negative correlation ($p < 0.05$) was found; there was no significant correlation in the control group. (Note: acceleration of the psychomotor tempo is characterized by shortening of the reaction time in the given test).

The overall score of the BEST test was correlated with the gait speed in seconds, with and without cognitive tasks, and evaluated by the Up and Go and TUG tests. In the experimental group there were significant negative correlations ($p < 0.01$) in both tests. In the control group a negative correlation ($p < 0.02$) was found in the Up and Go tests. There was no significant correlation in the TUG test. (Note: acceleration of gait speed is characterized by shortening of time in the given tests).

We also correlated the overall score of the BEST test with the BADL test that evaluated the performance of daily activities. In the experimental group there was a significant negative correlation ($p < 0.001$); but no significant correlation in the control group. (Note: improvement in the performance of daily activities is expressed by a score reduction in the given test).

Discussion

The purpose of this study was to examine the relationships between balance control and cognitive functions, gait speed, and daily activities after completing cognitive and motor training. In the experimental group, there were five significant correlations recorded between balance control and visuomotor coordination, psychomotor tempo, gait speed with and without cognitive tasks, and ADL. In the control group, one significant correlation was recorded between balance control and gait speed without cognitive tasks.

A significant relationship was noted in the experimental group between psychomotor tempo acceleration—reaction time shortening, and balance control improvement. A relationship was also seen, but only in the experimental group, between reaction time reduction in the test evaluating visuomotor coordination and balance control. We assume that these effects were due to performing the training of visuomotor coordination from the CogniPlus test batteries.

Further significant relationships were recorded in both groups between gait speed increase during single task executions and balance control improvement. Relationships also were noted between gait speed increases during the execution of dual tasks and between balance control improvements, but these occurred only in the experimental group. We assume that these effects were due to performing the training of attention intensity and executive functions from the CogniPlus test batteries.

A significant association was also recorded, but only in the experimental group, between balance control improvement and improvement in the execution of daily activities, expressed by the lower score in the BADLS test.

Many authors of cross-sectional studies have examined the relationship between the cognitive and physical performances of people with MCI [9, 10, 17]. McGough [10] found that slowing down of gait speed related to slowing down of executive functions in seniors with MCI who led a sedentary life. Worsening of executive functions related to worsening of ADL execution and disabilities. In our experimental group, a relationship was found between balance control improvement and improvement in execution of ADL after participants had accomplished the cognitive-motor training.

Tangen [17] examined the relationship between various aspects of balance and cognitive domains in patients with MCI. The study findings indicated that all aspects of balance control evaluated by the BESTest deteriorated with increasing severity of cognitive impairment, noting that executive function evaluated by TMT B plays an important role in balance control.

Similarly in our experimental group, a relationship was found between the improvement of balance control evaluated by the BESTest and the acceleration of psychomotor tempo in the TMT A test.

Mirleman [9] examined the association between performance on Timed Up and Go subtasks and MCI. He found that a mild cognitive deficit was related to worsening in the TUG test with a dual task. In our study, we observed the relationship between improvements in the given test and improvements in balance control after cognitive-motor training.

The correlations in our study point out the link between cognitive functions, balance control, and the execution of daily activities, which was more evident in the experimental group following cognitive-motor intervention.

Strengths, limitations, and future recommendations

The strength of this study is the relatively high response rate within our sample (85 %), and low loss to follow up. The limitations of the study were the small sample size and the lack of blinding to the intervention of the training personnel. Recommendations for future studies would include defining predictors of worsening balance control, with regard to worsening of cognitive function.

Practical conclusion

Our 10-week cognitive-motor training program confirmed more significant relationships between balance control, cognitive functions, gait speed, and ADL execution. Motor intervention had a less significant effect on these relationships'. Cognitive interventions should be an important part of motor interventions in the treatment of balance disorders.

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Compliance with ethical guidelines

Conflict of interest. None.

The research was approved by the Ethical Committee of the Highly Specialized Geriatric Institute of Saint Lukas in Kosice, Slovakia, which the work was undertaken and that it conforms to the provisions of the Declaration of Helsinki (as revised in Seoul 2008).

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Demenz stellt Krankenhäuser vor Herausforderungen

Insgesamt 40 % aller über 65-jährigen Patienten in Allgemeinkrankenhäusern weisen kognitive Störungen auf, fast jeder Fünfte leidet an Demenz. Zu diesem Ergebnis kommt die von der Robert Bosch Stiftung geförderte Studie „Demenz im Allgemeinkrankenhaus. Prävalenz und Versorgungssituation". Für die Studie haben Forscher von der Hochschule Mannheim und der Technischen Universität München über zwei Jahre rund 1500 Patienten untersucht und die Versorgungssituation in über 30 Krankenhäusern beurteilt. Die Studie belegt, dass Patienten mit Demenz besondere Anforderungen an das pflegerische und medizinische Personal stellen. Neben kognitiven Beeinträchtigungen zeigten nahezu 80 % zusätzliche Verhaltenssymptome wie nächtliche Unruhe, Umtriebigkeit und Aggressivität, die den Umgang mit den Patienten erschweren. Insgesamt nimmt die Versorgung deutlich mehr Zeit in Anspruch und ist mit zahlreichen Problemen in Pflege und Therapie verbunden. Erschwerend kommt hinzu, dass die Diagnose bei gut zwei Drittel der Demenzkranken zum Zeitpunkt der stationären Aufnahme nicht bekannt ist. Die Experten empfehlen deshalb entsprechende Untersuchungen. Der bei der Studie eingesetzte kurze Screeningtest erkenne auch leichte demenzielle Störungen zuverlässiger, als die üblicherweise von den Kliniken herangezogenen Verfahren, erklärt die Arbeitsgruppe. Das könne Krankenhäusern dabei helfen, Patientengruppen zu identifizieren, die besonders intensiver Betreuung und Pflege bedürfen. Umso leichter gelinge es, fachübergreifende Versorgungsschwerpunkte mit geschultem Personal einzurichten. Spezielle Betreuungsangebote sind nur selten vorhanden. Auch Pflege- und Betreuungskräfte mit spezieller Ausbildung sind aktuell die Ausnahme. Entsprechende Schulungen und Weiterbildungen zum Thema Demenz fehlen in den meisten Fällen, stellten die Forscher fest. Die Studie unterstreicht die Dringlichkeit des Problems, mit dem sich Krankenhäuser in Deutschland bereits seit einigen Jahren konfrontiert sehen, betont die Robert Bosch Stiftung. Die stationären Aufenthalte sind auch für die Patienten eine Herausforderung. Die fremde Umgebung und die unbekannten Abläufe können die Symptome der Demenz verschärfen und zu zusätzlichen Gesundheitsrisiken führen. Mit den jetzt vorliegenden Daten hätten Krankenhäuser endlich eine Planungsgrundlage, um die Versorgung von Patienten mit Demenz zu verbessern. Bereits 2012 hatte sich etwa jedes zehnte Krankenhaus in Deutschland für das Pilotprogramm „Menschen mit Demenz im Akutkrankenhaus" der Robert Bosch Stiftung beworben. Seitdem fördert die Stiftung zwölf Krankenhäuser in ganz Deutschland, die vorbildliche Konzepte für Patienten mit der Nebendiagnose Demenz in der Praxis umsetzen. Die dritte Ausschreibungsrunde des Förderprogramms startet ab sofort.

Quelle: Robert Bosch Stiftung
www.bosch-stiftung.de/demenz