Dexterity and Bimanual Coordination, Cognitive Function, Mental and Cognitive Wellbeing in People with Young Onset Dementia: A Case-Control Study

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Running head: Cognitive function and well-being in Young onset dementia

Abstract

BACKGROUND: Dexterity and bimanual coordination, cognitive function, and mental and cognitive wellbeing had not previously been examined in people with young onset dementia. Therefore, this study examined dexterity and bimanual coordination, cognitive function, and mental and cognitive wellbeing in people with young onset dementia (n=16), and age-matched healthy controls (n=17).

METHODS: Both groups completed the Purdue Pegboard Test (dexterity and bimanual coordination), Addenbrooke's Cognitive Examination III (ACE-III; cognitive function), General Anxiety Disorder-7 (GAD-7; general anxiety), Generic health-related quality of life measures (EQ-5D-3L; overall health), General Self-Efficacy Scale (GSE; self-efficacy), Patient Health Questionnaire (PHQ-9; depression) and The Pittsburgh Sleep Quality Index (PSQI; sleep quality).

RESULTS: The main findings of the present investigation were that people with young onset dementia displayed poorer dexterity and bimanual coordination, generic health-related quality of life analogue and generic self-efficacy compared to age-matched healthy controls. However, people with young onset dementia and age-matched healthy controls were comparable for anxiety, depression, generic health-related quality of life index, and sleep quality index.

CONCLUSION: This study highlights differences in dexterity and bimanual coordination, quality of life, and self-efficacy between people with young onset dementia and controls. People with young onset dementia exhibited poorer dexterity, generic health-related quality of life analogue, and self-efficacy. The study highlights the potential impacts of young onset dementia on dexterity, health-related quality of life, and self-efficacy. More longitudinal research is needed to assess the time course of this impact and explore support strategies.

Key words

Young-onset dementia; neurodegenerative disease; Dexterity and bimanual coordination; cognitive function; Anxiety; Health; Self-efficacy; Sleep, depression, comparative study, age-matched healthy controls, quality of life

Introduction

Dementia is a neurological condition characterised by a decline in cognitive function[1]. Several risk factors are linked to its development, including age, education level, diet, alcohol consumption, sleep patterns, smoking, and various chronic comorbidities[2]. Currently, more than 55 million people worldwide are living with dementia, projected to rise to 152 million by 2050[3]. The global economic burden of dementia is equally concerning, with the cost of care expected to soar to between $1.6-2.4 trillion by 2050[4]. Alzheimer's disease is currently the leading dementia in terms of incidence, representing 60% of dementia cases[5] which affects ~10% of people aged over 65 years of age[6]. Dementia affects multiple domains of cognitive function, including memory, attention, executive function, language and visuospatial abilities[7]. As these cognitive domains decline, individuals' capacity for independence diminishes, reducing their outlook on life[8].

Young onset dementia is the onset of dementia before the age of 65 years of age[9] and represents 5% of all dementia cases in the UK, and up to 3.9 million cases worldwide[10]. A systematic review highlighted there was an average time of 4.4 years between symptom onset and diagnosis of young onset dementia[9]. Young onset dementia is heterogenous in symptomology compared to late onset dementia, with early symptoms including behaviour change and difficulties with language[9]. The average life expectancy is 7.9 years from diagnosis, emphasising the aggressiveness of the condition[11]. Research concerning young onset dementia remains limited, with the largest body of research focused on late onset dementia. However, assuming early onset dementia is analogous with late onset dementia is invalid, and more research is required concerning young onset dementia, despite this only contributing 5% of total dementia cases.

Some previous literature has explored dexterity and bimanual coordination in individuals with dementia, primarily late onset dementia. Menengiç et al.[12] identified reduced dexterity test performance in individuals with Alzheimer's disease compared to healthy controls, with Alzheimer's disease patients significantly slower at the dominant hand nine hole peg test. Previous work by Starkstein et al.[13] found

that 144 of 552 Alzheimer's disease patients reported excessive anxiety and worry. This study used the diagnostic and statistical manual of mental disorders to examine anxiety in dementia patients. This comprehensive tool was used to assess the concurrence of anxiety and depression in relation to Alzheimer's disease diagnosis and the neuropsychological and functional impact anxiety exerted. More recent findings by Mendez [14] have further demonstrated the impact of anxiety and depression in dementia cases, stating that these symptoms often worsen throughout dementia prognosis. Health related quality of life is often impacted by these symptoms. This has previously been assessed in late onset dementia patients by Huang et al.[15] using the EuroQol-5 dimensions-5 levels (EQ-5D-5L; utility and visual analogue scale [VAS] scores), Mini-Mental State Examination (MMSE), and clinical dementia rating (CDR). The study highlighted activities of daily living, dementia severity, cognitive function, and depressive symptoms directly influence quality of life and these worsen throughout prognosis.[15]

Concerning depression in dementia patients, Tetsuka [16] highlighted in their neuropsychological review that out of 20,892 patients from 57 studies, depression prevalence in patients with mild cognitive impairment was 32%. Changes in daily life caused by dementia often contributes to anxiety and depression, leading to reduced self-efficacy and worse mental health. Regarding self-efficacy, dementia patients exhibit poorer self-efficacy compared to healthy controls, as demonstrated by Tonga et al. (2020)[17] utilising the GSE, Quality of Life in Alzheimer's Disease (QOL-AD) scale, and Hospital Anxiety and Depression Scale (HADS). These authors reported that self-efficacy often dictates anxiety and depression in dementia patients and increases in GSE may lead to better mental health outcomes.

Dementia is well known to disrupt sleep and has been demonstrated in much of the previous literature[18–21]. Indeed, a recent systematic review found across 11 studies that 24% of those with Alzheimer's disease reported sleep disturbance, and this number rose to 49% patients with Lewy Body dementia[18]. While these parameters have been investigated in late onset dementia ($\geq$65 years), there is a dearth of research in young onset dementia, which the present manuscript aimed to address.

The aim of this experiment was therefore to compare Dexterity and Bimanual Coordination, General Anxiety Disorder-7 (GAD-7; general anxiety), Generic health-related quality of life measures (EQ-5D-3L; overall health), General Self-Efficacy Scale (GSE; self-efficacy), Patient Health Questionnaire (PHQ-9; depression), and The Pittsburgh Sleep Quality Index (PSQI; sleep quality) between young onset dementia patients and age-matched healthy controls. We hypothesised *a priori* that people with young onset dementia would exhibit poorer values across all variables compared to healthy age-matched controls.

Methods

Participants

Thirty-four participants were initially recruited: 17 with young-onset dementia (YOD) via NHS clinical partners and 17 healthy age-matched controls via social media (X, formerly Twitter). One YOD participant withdrew due to an unrelated injury, resulting in a final sample of 33 (YOD: n=16; controls: n=17). Participants attended a single visit at the Cardiovascular Imaging Laboratory, University of the West of Scotland (Lanarkshire campus), between January and November 2023, where they completed the Purdue Pegboard Test (manual dexterity and coordination). Questionnaires assessing anxiety (GAD-7), depression (PHQ-9), self-efficacy (GSE), sleep quality (PSQI), and quality of life (EQ-5D-3L) were completed remotely via an online platform. Cognitive function was assessed in both groups using the Addenbrooke's Cognitive Examination-III (ACE-III) to provide a baseline cognitive profile, or "staging", common in dementia research. The study adhered to the Declaration of Helsinki and was approved by the NHS London Riverside Ethics Committee. Written informed consent was obtained from all participants. Descriptive statistics are presented in Table 1.

INSERT TABLE 1 ABOUT HERE

Protocol

Dexterity and Bimanual Coordination: Purdue Pegboard Test

Five values were obtained from the test battery, from the four tasks below, plus the sum of dominant hand (task 1), non-dominant hand (task 2), both hands (task 3), and assembly (task 4). Measurements were performed in following order:

1. Dominant hand (30 seconds)
2. Non-dominant hand (30 seconds)
3. Both hands (30 seconds)
4. Assembly (60 seconds)

For brevity and to avoid self-plagiarising, the test has been previously described, and published open access[22].

ACE-III

Cognitive function was assessed using the Addenbrooke's Cognitive Examination (ACE-III), comprising 19 tasks across five domains: attention (e.g. date recall, serial subtraction; scored /18), memory (e.g. word and historical fact recall; /26), fluency (word generation by letter; /14), language (sentence writing; /26), and visuospatial processing (e.g. clock drawing; /16).The maximum score was 100, with cut off points of <88 (suggestive of cognitive impairment) or <82 (suggestive of dementia)[23].

Mental and Cognitive Wellbeing

Mental and cognitive well-being were assessed using a series of questionnaires delivered via Microsoft Forms (Forms, Microsoft, Redmond, WA). Anxiety was measured using the General Anxiety Disorder assessment (GAD-7), a 7-item self-report tool taking ~5 minutes to complete. It evaluates how often participants felt worried, anxious, on edge, or restless over the past two weeks. Each item is rated 0–3 (0 = not at all; 3 = every day), with a maximum score of 21. Scores of 5, 10, and 15 indicate mild, moderate, and severe anxiety, respectively.

Depression was assessed with the 9-item Patient Health Questionnaire (PHQ-9), based on DSM-IV criteria. It asks how often participants experienced depressive symptoms affecting mood and daily functioning over the past two weeks. Items are rated 0–3, giving a total score of 0–27. Scores of 5–9 indicate mild, 10–14 moderate, and ≥20 severe depression.

Quality of life was evaluated using the European Quality of Life Five Dimension Questionnaire (EQ-5D-3L), which includes five domains: mobility, pain/discomfort, anxiety/depression, and usual activities. It takes ~3 minutes to complete. Each item is rated 0–3, producing a five-dimension profile used to calculate an index score (0–1), where higher values reflect better health. Participants also rated their overall health on a visual analogue scale (VAS) from 0 to 100.

Self-efficacy was measured using the 10-item General Self-Efficacy Scale (GSE), which assesses optimistic beliefs in handling difficult life situations. Items are rated on a 4-point Likert scale (1 = not at all; 4 = exactly true), yielding a total score of 10–40, with higher scores indicating stronger perceived self-efficacy.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a self-report tool covering the previous month. It includes 19 items grouped into seven components: subjective sleep quality, sleep latency, duration, efficiency, disturbances, use of medication, and

daytime dysfunction. Each component is rated 0–3 and summed for a total score out of 21, where higher scores indicate poorer sleep quality. Participants and their carers received guidance from the research team on how to complete the forms, which were distributed via email using URLs.

Statistical Analysis

Data were assessed for normal distribution and homogeneity of variance. To assess the differences of dependent variables, independent samples t-tests were performed. Data were analysed using R Studio (2023.12.0+369). Data are presented without subjective terminology and α levels are reported as exact p values, without dichotomous interpretation of 'significant' or 'non-significant' as advised by the American Statistical Association[24]. Effect size for paired comparisons is presented as Cohen's *d* whereby the difference in means between two samples was divided by the pooled standard deviation (SD). Thresholds of 0.2, 0.5, and 0.8 for small, moderate, and large effects were used for Cohen's *d*[25]. Figures were generated in R Studio (2023.12.0+369) and displayed as grouped dot plots with mean and median lines (dependant on satisfaction of assumptions) as recommended by Drummond and Vowler[26,27]. Data are presented in text as mean ± SD.

Results

Descriptive participant parameters are displayed in Table 1. Dexterity and bimanual coordination (figure 1), Generalised Anxiety Disorder-7 (figure 2), Patient Health Questionnaire-9 (figure 3), Euro Quality of Life – 5 Dimension – 3 Levels (figure 4), General Self Efficacy (figure 5) and Pittsburgh Sleep Quality Index (figure 6) are visualised below. Pairwise comparisons suggest there were large differences on all dexterity parameters (left $p=0.013$, $d=1.0$; large effect, right $p=0.008$, $d=1.0$; large effect, both $p<0.001$, $d=1.4$; large effect, left + right + both $p<0.001$, $d=1.3$; large effect, assembly $p<0.001$, $d=1.6$; large effect). The young onset dementia group had worse EQ-5D-3L analogue scores

(p=0.007, d=1.1; large effect). However, no differences were evident for index scores (p=0.137, d=0.6; moderate effect). Controls also had a greater GSE score than the young onset dementia group (p<0.001, d=1.3; large effect). There were no differences found in in GAD-7 scores (p=0.483, d=0.2; small effect), PHQ-9 scores (p=0.287, d=0.2; small effect), or Global PSQI scores (p=0.889, d=0.2; small effect).

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Discussion

The purpose of this study was to compare dexterity and bimanual coordination, and mental and cognitive wellbeing between individuals with young onset dementia and age-matched healthy controls. The main findings were that differences existed in all dexterity parameters, EQ5D – 3 Levels analogue score and GSE score. There were no differences between groups in EQ5D – 3 Levels index scores, GAD-7, PHQ-9 and Pittsburgh Sleep Quality Index scores. Thus, our hypothesis that all parameters would be poorer in people with young onset dementia compared to controls was only partially supported.

We found the young onset dementia group performed worse than controls on the Purdue Pegboard Test. Although previous literature concerning dexterity in young onset dementia is scarce, our findings agree with previous literature suggesting worse dexterity in late onset dementia compared to cognitively healthy adults[12]. Within dementia research, reduced dexterity has been shown to have a close relationship with worse cognitive function [28,29]. This reduction in motor function has a profound impact on the ability to complete daily activities, significantly and negatively influencing quality of life[30]. Areas of the brain such as the primary motor cortex are responsible for planning and executing fine motor movements[31]. Dementia can cause atrophy to this brain area, reducing motor control and coordination[32].

The present study found no differences in EQ-5D-3L index score. Conversely, the analogue score was inferior in the young onset dementia group compared to controls, confirming previous observations[33]. The reason for this difference was likely caused by the sudden loss of independence post-young onset dementia diagnosis, whereafter people with young onset dementia become reliant on caregivers[10]. The current study observed lower GSE scores in the young onset dementia group, consistent with previous literature[10], likely due to young onset dementia patients' perceptions declining capacity[17].

There were no differences in GAD-7 values. Previous work has found anxiety is a common feature of the young onset dementia process, and is associated to the early awareness of cognitive decline and a reshaping of one's life that may include medical retirement[34]. People with young onset dementia have greater pre-disposition to anxiety than late onset dementia, partly due to the unique challenges faced at the earlier stage of life[35]. The present study may have observed no differences between those diagnosed with dementia and controls due to having a lower sample size. To demonstrate this, a post-hoc power calculation using our observed effect size (0.2) for GAD-7 data, statistical power of 0.8, and α of 0.05 resulted in a sample size of 393 per group. This was beyond the scope of the current investigation as our primary outcome variable was maximal oxygen uptake[36].

The present study found no differences in PHQ-9 data between groups. Previous research has reported depression is prevalent in young onset dementia, mainly due to apathy accompanying diagnosis[37].

Depressive symptoms are more common in young onset dementia than in late onset dementia, and a recent meta-analysis observed 25% prevalence of depression in late onset dementia[38], with other studies reporting this prevalence as high as 66% in young onset dementia[39]. It is possible the present study found no differences between groups for depressive symptoms due to the small sample size. The small sample makes it difficult to arrive at a consensus and results from this study cannot be extrapolated across the clinical population until this design is scaled up.

No differences were detected between groups in PSQI data. Previous work has demonstrated poor sleep quality in people diagnosed with dementia[40], however, have failed to demonstrate a significant difference between dementia groups and control groups, similar to the present findings. Therefore, more research may be needed, especially in young onset dementia patients.

Some findings observed herein were not reflective of the existent literature. This may be due to reasons highlighted previously such as participant age and stage of diagnosis. Our recruitment strategy may partially explain this, as study information and invitations to participate were provided at the point of diagnosis from our participant identification centre. Therefore, young onset dementia patients who are further on in prognosis are unlikely to yield similar findings[41].

Implications

Dexterity and bimanual coordination, and mental and cognitive wellbeing had not been reported within the same study until now. Therefore, we hope this novel investigation can help guide future work by adding information related to these domains. We have highlighted key areas of impairment across Purdue pegboard test, EQ-5D-3L analogue score, and General Self Efficacy scale score.

Strengths and Limitations

A key strength of the current study was the target population, focussing on those with young onset dementia addressed an under-represented population, paving the way for further research in the area. However, this study is not without limitations, including a modest sample size. To address this, we communicated magnitude-based inferences and precise α values instead of binary 'significance' classifications. This was necessary due to scant normative values in young onset dementia. Secondly,

young onset dementia is progressive and therefore data from this study may not be extrapolated to young onset dementia patients in the latter stages of prognosis. To address this, future research should consider cross sectional designs from people at multiple stages of prognosis.

We revealed stark variance in the young onset dementia group exhibited for the Purdue pegboard test, EQ-5D-3L analogue score and General Self Efficacy scale score. The control group exhibited smaller variance, likely due to its more homogeneous composition. We postulate this was due to a broader range of symptoms inherent to their diagnosis and/or different duration of illness[42].

Conclusion

The identified deficits in dexterity and bimanual coordination, EQ-5D-3L analogue score and general self-efficacy may contribute to disease burden, emphasising the need to recognise and address these issues to improve quality of life. We identified differences between the young onset dementia group and controls in dexterity, health rating and self-efficacy. To confirm the findings described above, we suggest more studies are completed longitudinally and at scale to broaden understanding on how diagnosis interacts with the parameters studied herein. This research would lay the foundations for designing and evaluating complex support packages.

Authorship contributions according to the CRediT taxonomy

Conceptualisation, L.D.H., N.E.M.S-H., N.F.S., S.M., D.T.; methodology, L.D.H., E.C.J.B., N.E.M.S-H., N.F.S., D.S.B., M.M., D.T.; software, L.D.H., E.C.J.B., N.F.S., D.S.B., M.M.; validation, L.D.H., E.C.J.B., N.E.M.S-H., N.F.S., D.S.B., M.M., S.M., B.C., D.T.; formal analysis, L.D.H., E.C.J.B., N.E.M.S-H., D.S.B., ; investigation, L.D.H., E.C.J.B., N.E.M.S-H., N.F.S., D.S.B., M.M.; resources, L.D.H., N.E.M.S-H., N.F.S., D.S.B., S.M., D.T.; data curation, E.C.J.B.; writing—original draft preparation, L.D.H., E.C.J.B.; writing—review and editing, L.D.H., E.C.J.B., N.E.M.S-H., N.F.S., D.S.B., M.M., S.M., B.C., D.T. ; visualisation, E.C.J.B.; supervision, L.D.H.; project administration, L.D.H., E.C.J.B., S.M., B.C., D.T.; funding acquisition, L.D.H., N.E.M.S-H., N.F.S., D.S.B., S.M., D.T. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest statement

The submitted work was not carried out in the presence of any personal, professional, or financial relationships that could potentially be construed as a conflict of interest.

References

1. Aarsland D. Epidemiology and Pathophysiology of Dementia-Related Psychosis. *J Clin Psychiatry*. 2020;81(5):AD19038BR1C. doi:10.4088/JCP.AD19038BR1C

2. Anstey KJ, Ee N, Eramudugolla R, Jagger C, Peters R. A Systematic Review of Meta-Analyses that Evaluate Risk Factors for Dementia to Evaluate the Quantity, Quality, and Global Representativeness of Evidence. *J Alzheimers Dis*. 2019;70(s1):S165-S186. doi:10.3233/JAD-190181

3. Nichols E, Steinmetz JD, Vollset SE, et al. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. *The Lancet Public Health*. 2022;7(2):e105-e125. doi:10.1016/S2468-2667(21)00249-8

4. Pedroza P, Chakrabarti S, Chapin A, Liu A, Matyasz T, Dieleman JL. O5-08-02: COSTS OF ALZHEIMER'S DISEASE AND DEMENTIA IN 188 COUNTRIES. *Alzheimer's & Dementia*. 2019;15(7S_Part_31). doi:10.1016/j.jalz.2019.06.4877

5. Rizzi L, Rosset I, Roriz-Cruz M. Global Epidemiology of Dementia: Alzheimer's and Vascular Types. *BioMed Research International*. 2014;2014:1-8. doi:10.1155/2014/908915

6. Mosconi L. Glucose metabolism in normal aging and Alzheimer's disease: Methodological and physiological considerations for PET studies. *Clin Transl Imaging*. 2013;1(4). doi:10.1007/s40336-013-0026-y

7. Pal A, Pegwal N, Kaur S, Mehta N, Behari M, Sharma R. Deficit in specific cognitive domains associated with dementia in Parkinson's disease. *Journal of Clinical Neuroscience*. 2018;57:116-120. doi:10.1016/j.jocn.2018.08.016

8. Emmady PD, Schoo C, Tadi P. Major Neurocognitive Disorder (Dementia). In: *StatPearls*. StatPearls Publishing; 2025. Accessed January 28, 2025. http://www.ncbi.nlm.nih.gov/books/NBK557444/

9. Hendriks S, Peetoom K, Bakker C, et al. Global Prevalence of Young-Onset Dementia: A Systematic Review and Meta-analysis. *JAMA Neurol*. 2021;78(9):1080-1090. doi:10.1001/jamaneurol.2021.2161

10. Rodgers C, Rogerson D, Stevenson J, Porock D. Physical activity for people with young-onset dementia and carers: protocol for a scoping review. *Syst Rev*. 2018;7(1):36. doi:10.1186/s13643-018-0698-5

11. Brodaty H, Seeher K, Gibson L. Dementia time to death: a systematic literature review on survival time and years of life lost in people with dementia. *Int Psychogeriatr*. 2012;24(7):1034-1045. doi:10.1017/S1041610211002924

12. Menengiç KN, Yeldan İ, Cınar N, Şahiner TA. Effectiveness of home-based telerehabilitation in mild to moderate Alzheimer's disease: A randomised controlled study. *Alzheimer's & Dementia*. 2021;17(S8):e053406. doi:10.1002/alz.053406

13. Starkstein SE, Jorge R, Petracca G, Robinson RG. The Construct of Generalized Anxiety Disorder in Alzheimer Disease. *The American Journal of Geriatric Psychiatry*. 2007;15(1):42-49. doi:10.1097/01.JGP.0000229664.11306.b9

14. Mendez MF. The Relationship Between Anxiety and Alzheimer's Disease. *Journal of Alzheimer's Disease Reports*. 2021;5(1):171-177. doi:10.3233/ADR-210294

15. Huang X, Zhao X, Li B, et al. Comparative efficacy of various exercise interventions on cognitive function in patients with mild cognitive impairment or dementia: A systematic review and network meta-analysis. *J Sport Health Sci*. 2022;11(2):212-223. doi:10.1016/j.jshs.2021.05.003

16. Tetsuka S. Depression and Dementia in Older Adults: A Neuropsychological Review. *Aging and disease*. 2021;12(8):1920. doi:10.14336/AD.2021.0526

17. Tonga JB, Eilertsen DE, Solem IKL, Arnevik EA, Korsnes MS, Ulstein ID. Effect of Self-Efficacy on Quality of Life in People With Mild Cognitive Impairment and Mild Dementia: The Mediating Roles of Depression and Anxiety. *Am J Alzheimers Dis Other Demen*. 2020;35:1533317519885264. doi:10.1177/1533317519885264

18. Koren T, Fisher E, Webster L, Livingston G, Rapaport P. Prevalence of sleep disturbances in people with dementia living in the community: A systematic review and meta-analysis. *Ageing Research Reviews*. 2023;83:101782. doi:10.1016/j.arr.2022.101782

19. Mander BA, Winer JR, Jagust WJ, Walker MP. Sleep: A Novel Mechanistic Pathway, Biomarker, and Treatment Target in the Pathology of Alzheimer's Disease? *Trends in Neurosciences*. 2016;39(8):552-566. doi:10.1016/j.tins.2016.05.002

20. McCleery J, Sharpley AL. Pharmacotherapies for sleep disturbances in dementia. Cochrane Dementia and Cognitive Improvement Group, ed. *Cochrane Database of Systematic Reviews*. 2020;2020(11). doi:10.1002/14651858.CD009178.pub4

21. Richardson K, Loke YK, Fox C, et al. Adverse effects of Z-drugs for sleep disturbance in people living with dementia: a population-based cohort study. *BMC Med*. 2020;18(1):351. doi:10.1186/s12916-020-01821-5

22. Sanal-Hayes NEM, Hayes LD, Mclaughlin M, Berry ECJ, Sculthorpe NF. People with Long COVID and ME/CFS Exhibit Similarly Impaired Dexterity and Bimanual Coordination: A Case-Case-Control Study. *The American Journal of Medicine*. Published online February 2024:S0002934324000913. doi:10.1016/j.amjmed.2024.02.003

23. Beishon LC, Batterham AP, Quinn TJ, et al. Addenbrooke's Cognitive Examination III (ACE-III) and mini-ACE for the detection of dementia and mild cognitive impairment. Cochrane Dementia and Cognitive Improvement Group, ed. *Cochrane Database of Systematic Reviews*. 2019;2019(12). doi:10.1002/14651858.CD013282.pub2

24. Hurlbert SH, Levine RA, Utts J. Coup de Grâce for a Tough Old Bull: "Statistically Significant" Expires. *The American Statistician*. 2019;73(sup1):352-357. doi:10.1080/00031305.2018.1543616

25. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol*. 2013;4. doi:10.3389/fpsyg.2013.00863

26. Drummond GB, Vowler SL. Do as you would be done by: write as you would wish to read. *The Journal of Physiology*. 2012;590(24):6251-6254. doi:10.1113/jphysiol.2012.248278

27. Drummond G, Vowler S. Show the data, don't conceal them. *British J Pharmacology*. 2011;163(2):208-210. doi:10.1111/j.1476-5381.2011.01251.x

28. De Paula JJ, Albuquerque MR, Lage GM, Bicalho MA, Romano-Silva MA, Malloy-Diniz LF. Impairment of fine motor dexterity in mild cognitive impairment and Alzheimer's disease dementia: association with activities of daily living. *Rev Bras Psiquiatr*. 2016;38(3):235-238. doi:10.1590/1516-4446-2015-1874

29. Kobayashi-Cuya KE, Sakurai R, Suzuki H, Ogawa S, Takebayashi T, Fujiwara Y. Observational Evidence of the Association Between Handgrip Strength, Hand Dexterity, and Cognitive Performance in Community-Dwelling Older Adults: A Systematic Review. *Journal of Epidemiology*. 2018;28(9):373-381. doi:10.2188/jea.JE20170041

30. Wang Z, Wang J, Guo J, et al. Association of Motor Function With Cognitive Trajectories and Structural Brain Differences: A Community-Based Cohort Study. *Neurology*. 2023;101(17). doi:10.1212/WNL.0000000000207745

31. Yokoi A, Arbuckle SA, Diedrichsen J. The Role of Human Primary Motor Cortex in the Production of Skilled Finger Sequences. *J Neurosci*. 2018;38(6):1430-1442. doi:10.1523/JNEUROSCI.2798-17.2017

32. Vidoni ED, Thomas GP, Honea RA, Loskutova N, Burns JM. Evidence of Altered Corticomotor System Connectivity in Early-Stage Alzheimer's Disease. *Journal of Neurologic Physical Therapy*. 2012;36(1):8-16. doi:10.1097/NPT.0b013e3182462ea6

33. Dixit D, Spreadbury J, Orlando R, Hayward E, Kipps C. Quality of Life Assessments in Individuals With Young-Onset Dementia and Their Caregivers. *J Geriatr Psychiatry Neurol*. 2021;34(5):426-433. doi:10.1177/0891988720933348

34. Popok PJ, Reichman M, LeFeber L, Grunberg VA, Bannon SM, Vranceanu AM. One Diagnosis, Two Perspectives: Lived Experiences of Persons With Young-Onset Dementia and Their Care-Partners. Bowers BJ, ed. *The Gerontologist*. 2022;62(9):1311-1323. doi:10.1093/geront/gnac050

35. Kimura N, Aota T, Aso Y, et al. Predicting positron emission tomography brain amyloid positivity using interpretable machine learning models with wearable sensor data and lifestyle factors. *Alzheimer's research & therapy*. 2023;15(1):212. doi:10.1186/s13195-023-01363-x

36. Hayes LD, Berry ECJ, Sanal-Hayes NEM, et al. Body Composition, Vascular Health, Cardiorespiratory Fitness, Lung Function, Muscle Architecture, and Physical Activity in People with Young Onset Dementia: A Case-Control Study. *The American Journal of Medicine*. 2025;138(2):277-286.e1. doi:10.1016/j.amjmed.2024.08.027

37. Yoo H, Kim H, Koh I, Lee K, Ok J. Effect of Metabolic Syndrome on the Incidence of Dementia Based on National Insurance Data in Korea. *Metabolic Syndrome and Related Disorders*. Published online November 9, 2021:met.2021.0046. doi:10.1089/met.2021.0046

38. Kuring JK, Mathias JL, Ward L. Prevalence of Depression, Anxiety and PTSD in People with Dementia: a Systematic Review and Meta-Analysis. *Neuropsychol Rev*. 2018;28(4):393-416. doi:10.1007/s11065-018-9396-2

39. Yeung J, Jones A, Jhangri GS, Gibson W, Hunter KF, Wagg A. Toileting Disability in Older People Residing in Long-term Care or Assisted Living Facilities: A Scoping Review of the Literature. *Journal of Wound, Ostomy & Continence Nursing*. 2019;46(5):424-433. doi:10.1097/WON.0000000000000575

40. López-García A, López-Fernández RM, Martínez-González-Moro I. Analysis of Sleep Quality in People With Dementia: A Preliminary Study. *Gerontology and Geriatric Medicine*. 2023;9:23337214231151473. doi:10.1177/23337214231151473

41. Draper B, Withall A. Young onset dementia: Young onset dementia. *Intern Med J*. 2016;46(7):779-786. doi:10.1111/imj.13099

42. Kuruppu D, Matthews B. Young-Onset Dementia. *Semin Neurol*. 2013;33(04):365-385. doi:10.1055/s-0033-1359320