PREPRINT

Physical activity cancels the negative impact of adverse childhood experiences and depression on functional dependence

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ABSTRACT

Adverse childhood experiences, depression, and functional dependence are inter-related. However, mechanisms underlying this relation remain unclear. Here, we investigated the potential of depression to mediate the effect of adverse childhood experiences on functional dependence in older age and whether physical activity moderated this mediation. Data from 25,775 adults aged 62±9 years from the Survey of Health Ageing and Retirement in Europe (SHARE) was used in adjusted linear mixed-effect models to test whether depression mediated the associations between adverse childhood experiences and functional dependence in activities of daily living (ADL) and instrumental activities of daily living (IADL) and whether physical activity moderated these mediations. As expected, adverse childhood experiences were positively associated with ADL (b = .040 for 0 vs. 1 and b = .067 for 0 vs. ≥2 adverse childhood experiences) and IADL (b = .046 for 0 vs. 1 and b = .076 for 0 vs. ≥2 adverse childhood experiences). Both associations were mediated by depression. Physical activity reduced the effect of adverse childhood experiences on depression (b = -.060 for 0 vs. 1 and b = -.135 for 0 vs. ≥2 adverse childhood experiences) and canceled the effect of depression on functional dependence in ADL (b = .073) and IADL (b = .100), thereby eliminating the effect of adverse childhood experiences on functional dependence. Physical activity cancels the impact of adverse childhood experiences on functional dependence. In inactive individuals, the effect of adverse childhood experiences on functional dependence (ADL and IADL) is mediated by depression.

1. INTRODUCTION

In a recent systematic review, Hughes et al. (2017) demonstrated that adverse childhood experiences, such as neglect and household dysfunction, were associated with the twenty-three health outcomes identified in their review (e.g., depression, anxiety, physical inactivity, obesity). While these results highlight the pervasive harms that adverse childhood experiences place on multiple dimensions of health, they do not reveal the nature of the relations linking adverse childhood experiences and health outcomes. Assessing whether these relations are direct or indirect (i.e., explained by an intermediary variable) and whether they can be attenuated or eliminated through other factors would refine our understanding of the mechanisms underlying these relations.

Functional dependence is one of the health outcomes that has been associated with adverse childhood experiences (Laditka and Laditka, 2018; Amemiya et al., 2018). It is typically assessed through performance in activities of daily living (ADL; Katz et al., 1963) and instrumental activities of daily living (IADL; Lawton and Brody, 1969), with ADL referring to more basic activities (e.g., walking, eating, bathing) than IADL (e.g., shopping, preparing meal, housekeeping). Older adults who perform these activities without limitations have life expectancies 5 years longer than those with functional limitations (Keeler et al., 2010) and are more satisfied with their life (Cummings, 2002). Understanding the mechanisms underlying the associations between adverse childhood experiences and functional dependence could reveal new ways to increase life expectancy and well-being.

Depression, a mood disorder that causes a persistent feeling of sadness and loss of interest (American Psychiatric Association, DSM-5 Task Force, 2013), may be critical in understanding the relation between adverse childhood experiences and functional dependence. Indeed, etiological models for depression consider stressful experiences, such as adverse childhood events, as depression triggers (Monroe and Simons, 1991). Recent results supported these models by showing a strong positive relationship between adverse childhood experiences and the probability of depressive disorders in late adulthood (Chapman et al., 2004; Angelini et al., 2016), thereby supporting the theoretical link between adverse childhood experiences and depression. Additionally, studies have shown an association between depression and functional dependence (Braune and Berger, 2005; Ormel et al., 1994; Shrira and Litwin, 2014; Wada et al., 2005). The mechanisms underlying this association could lie in the main symptom of depression, the "lack of interest to all or most things" (Rosenström and Jokela, 2017), which can potentially decrease the frequency an individual engages in ADL and IADL. On In the long term, this decreased frequency could impact the ability to perform these activities, especially in aging, by further increasing the age-related decline of movement control such as postural balance (Boisgontier et al., 2017) and bimanual coordination (Maes et al., 2017).

In sum, data support the effect of adverse childhood experiences on functional dependence and depression, and depression on functional dependence, thereby suggesting that depression could mediate the effect of adverse childhood experiences on functional dependence. However, to the best of our knowledge, no study has formally tested for this potential mechanism.

While understanding the mechanisms underlying the relation between adverse childhood experiences and health outcomes is important from a fundamental research perspective, this knowledge could inform clinical and political decisions aiming at improving health. To address this point, we investigated whether protective factors could attenuate the relations linking adverse childhood experiences, depression, and functional dependence. We focused on physical activity, a low-cost and safe factor shown to benefit healthy aging (Bauman et al., 2016). Physical activity reduces the risk of developing depression (Chekroud et al., 2018; Teychenne et al., 2010) and decreases functional dependence (Tak et al., 2013). Therefore, physical activity could have a protective effect on functional dependence by attenuating the association between adverse childhood experiences and depression, and between depression and functional dependence. To the best of our knowledge, no study has yet examined this possibility.

This study aimed to examine whether depression explains the effect of adverse childhood experiences on functional dependence in older age and whether physical activity can reduce this negative impact of adverse childhood experiences. We hypothesized that the effect of adverse childhood experiences on functional dependence is mediated by depression and that this mediation is moderated by physical activity.

2. METHODS
2.1. Study population and design
Our analyses used data from the Survey of Health, Ageing and Retirement in Europe (SHARE), a longitudinal (12 years: 2004-2015; 6 waves; data collection every 2 years), cross-national (14 European countries) study of adults aged 50 years or older (Börsch-Supan et al., 2013). Functional dependence in ADL and IADL, depression and physical activity were assessed at the first, second, fourth, fifth, and sixth waves. Retrospective adverse childhood experiences were assessed at the third wave. Participants included in the analysis were aged 50 to 96 years and had completed the third wave with at least one measure of ADL (or IADL), depression, and physical activity. SHARE was approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

2.2. Variables
2.2.1. Predictor: Adverse childhood experiences
Adverse childhood experiences are traumatic events that affect children or adolescents directly or indirectly through their living environments and are out of a child's or adolescent's control (Felitti et al., 1998; Hughes et al., 2017). We carefully screened SHARE for variables that matched with this definition of adverse childhood experiences and included 6 binary indicators reflecting specific adverse childhood experiences

before the age of 16 years: child in care (living in a children's home or with a foster family), parental death (father, mother, or both), parental mental illness, parental drinking abuse, period of hunger, and property taken away. By combining the information of these 6 indicators, we computed a 3-level categorical variable of participants with no adverse childhood experience (i.e., participants who answered "no" to all categories filled out), 1 adverse childhood experience (i.e., participants who answered "yes" to only 1 category filled out), and with 2 or more adverse childhood experiences (i.e., participants who answered "yes" to at least 2 categories filled out). Participants with missing data for all 6 categories were excluded. When data were missing for adverse childhood experiences, the score was computed based on the available indicators to keep the maximum number of participants in the analyses (Solís et al., 2015).

2.2.2. Outcomes: Functional dependence
Two outcomes were used to measure functional dependence: the number of functional limitations in ADL and IADL. The measure of ADL based on the validated index of Katz et al. (1963) included 6 everyday self-care activities: dressing (including putting on shoes and socks), walking across a room, bathing or showering, eating, getting in or out of bed, and using the toilet (including getting up or down). The number of functional limitations in ADL was summed up resulting in a score ranging from 0 to 6. Higher scores were indicative of higher functional dependence (Landös et al., In press).
The measure of IADL based on the validated index of Lawton and Brody (1969) included 7 activities: using a map to figure out how to get around in a strange place, preparing a hot meal, shopping for groceries, making telephone calls, taking medications, doing work around the house or garden, and managing money (such as paying bills and keeping track of expenses). Scores ranged from 0 to 7 and higher scores were indicative of higher functional dependence (Landös et al., In press).

2.2.3. Mediator: Depression
Depression was measured using the EURO–D scale (Copeland et al., 2004; Prince et al., 1999) including 12 items: depressed mood, pessimism, wishing death, guilt, sleep, interest, irritability, appetite, fatigue, concentration, enjoyment, and tearfulness. Each item was scored 0 (symptom not present) or 1 (symptom present), generating an ordinal scale ranging from 0 to 12.

2.2.4. Moderator: Physical activity
Participants who engaged in activities that require vigorous, moderate, or low level of energy more than once a week were classified as physically active and the other participants were classified as inactive (Cheval et al., 2018). Specifically, two items were used to assess the usual level of physical activity over a week (Lindwall et al., 2011; de Souto Barreto et al., 2017). The first item assessed vigorous physical activity ("How often do you engage in vigorous physical activity, such as sports, heavy housework, or a job that involves physical labor?"). The second item assessed moderate physical activity ("How often do you engage in activities that require a low or moderate level of energy such as gardening, cleaning the car, or doing a walk?"). Participants answered by using a four-point scale (1 = more than once a week; 2 = once a week; 3 = one to three times a month; 4 = hardly ever, or never). Participants who answered "1" to either or both items were classified as physically active and the other participants were classified as inactive (Cheval et al., 2018).

2.2.5. Covariates
We considered age at baseline, wave (i.e., time), gender (male, female), country of residence (Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Poland, Spain, Sweden, Switzerland), birth cohort (1914–1918 and 1939–1945 wars, 1929–1938 Great Depression, no war and no economic crisis: before 1913, between 1919 and 1928, and after 1945), participant attrition (dropout, i.e., participants who did not respond to both waves 5 and 6; death, i.e., participants who died during the survey), childhood socioeconomic circumstances (Supplementary Material), and childhood health problems (Supplementary Material) as covariates.

2.3. Statistical analyses

2.3.1. Mediation by depression

The mediation effect of depression on the association between adverse childhood experiences and functional dependence was analyzed using linear mixed-effect models, which account for the nested structure of the data (e.g., multiple observations within a single participant), thereby providing accurate parameter estimates with acceptable type I error rates (Boisgontier and Cheval, 2016). The random structure encompassed random intercepts for participants and random linear slopes for waves at the level of participants. These random slopes estimated each participant's linear growth trajectory over the waves of the study (i.e., 12-years). The mediation was assessed using the component approach (Yzerbyt et al., In press). To demonstrate mediation, three models needed to be tested (Baron and Kenny, 1986; Judd and Kenny, 1981; Yzerbyt et al., In press). Model 1 (Equation 1) tested the effect of adverse childhood experiences on functional dependence, adjusting for prior confounders. This model included interaction terms between age at baseline and time (linear and quadratic) to adjust for the influence of age on the rate of increasing dependence over the waves. Waves were centered on the first wave of SHARE to estimate the main effects at the baseline assessment. Quadratic time accounted for potential accelerated rates of increasing functional dependence over the waves. Model 2 (Equation 2) tested the effect of adverse childhood experiences on depression. In Model 3 (Equation 3), depression (the potential mediator) and its interaction with waves (linear and quadratic) were added to Model 1.

$$
\begin{aligned}
Functional\ Dependence_{ij} \\
= (\beta_0 + \theta_{0j}) + \beta_1 \text{Age}_j \times (\beta_2 + \gamma_{2j})\ \text{Wave}_{ij} \\
+ \beta_1 \text{Age}_j \times \beta_3\ \text{Squared Wave}_{ij} + \beta_4 \text{Gender}_j + \beta_5 \text{Country}_j \\
+ \beta_6 \text{Birth Cohort}_j + \beta_7 \text{Dropout}_j \\
+ \beta_8\ \text{Childhood Socioeconomic Circumstances}_j \\
+ \beta_9\ \text{Childhood Health Problems}_j \\
+ \beta_{10}\ \text{Adverse Childhood Experience}_j + \epsilon_{ij}
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
Depression_{ij} = (\beta_0 + \theta_{0j}) + \beta_1 \text{Age}_j \times (\beta_2 + \gamma_{2j})\ \text{Wave}_{ij} \\
+ \beta_1 \text{Age}_j \times \beta_3\ \text{Squared Wave}_{ij} + \beta_4 \text{Gender}_j + \beta_5 \text{Country}_j \\
+ \beta_6 \text{Birth Cohort}_j + \beta_7 \text{Dropout}_j \\
+ \beta_8\ \text{Childhood Socioeconomic Circumstances}_j \\
+ \beta_9\ \text{Childhood Health Problems}_j \\
+ \beta_{10}\ \text{Adverse Childhood Experience}_j + \epsilon_{ij}
\end{aligned}
\tag{2}
$$

$$
\begin{aligned}
Functional\ Dependence_{ij} \\
= (\beta_0 + \theta_{0j}) + \beta_1 \text{Age}_j \times (\beta_2 + \gamma_{2j})\ \text{Wave}_{ij} \\
+ \beta_1 \text{Age}_j \times \beta_3\ \text{Squared Wave}_{ij} + \beta_4 \text{Gender}_j + \beta_5 \text{Country}_j \\
+ \beta_6 \text{Birth Cohort}_j + \beta_7 \text{Dropout}_j \\
+ \beta_8\ \text{Childhood Socioeconomic Circumstances}_j \\
+ \beta_9\ \text{Childhood Health Problems}_j \\
+ \beta_{10}\ \text{Adverse Childhood Experiences}_j + \beta_{11}\ \text{Depression}_j \times (\beta_2 \\
+ \gamma_{2j})\ \text{Wave}_{ij} + \beta_{11}\ \text{Depression}_j \times \beta_3\ \text{Squared Wave}_{ij} + \epsilon_{ij}
\end{aligned}
\tag{3}
$$

where $Functional\ Dependence_{ij}$ is the jth participant's ADL or IADL dependence score on wave i, β_0 to β_{10} are the fixed effect coefficients, θ_{0j} is the random effect for the jth participant (random intercept), γ_{2j} is the random effect for wave for the jth participant (random slope), and ϵ_{ij} is the error term.

To examine whether depression mediated the effect of adverse childhood experiences on functional dependence, four conditions must be met (Baron and Kenny,1986; Judd and Kenny, 1981; Muller et al., 2015). In Equation 1, there must be a significant effect of adverse childhood experiences on functional dependence. In Equation 2, there must be a significant effect of adverse childhood experiences on depression. In Equation 3, there must be an effect of depression on functional dependence, controlling for the effect of adverse childhood experiences. Finally, in Equation 3, the residual direct effect of adverse childhood experiences on functional dependence should be smaller than the effect of adverse childhood experiences in Equation 1. This component approach to the assessment of mediation was preferred over the index approach (Hayes, 2013), because the later has shown higher risk of false positives (Type I errors; Yzerbyt et al., In press). The percentage of decrease in the effect of adverse childhood experiences on functional dependence between the models without (1) and with (3) the mediating variable was calculated as follows: $(b_{model1} - b_{model3}) \times (b_{model1})^{-1} \times 100$. These percentages provided an estimate of the proportional influence of the potential mediating variable (depression) on the relation between adverse childhood experiences and functional dependence.

2.3.2. Moderation by physical activity

The moderating effect of physical activity on the direct and indirect association between adverse childhood experiences and functional dependence was analyzed using three models (Muller et al., 2015). Adding an adverse childhood experiences × physical activity interaction term in Equation 1 allowed the overall effect of adverse childhood experiences on functional dependence (Model 4) to be moderated by physical activity. Adding an adverse childhood experiences × physical activity interaction term in Equation 2 allowed the effect of adverse childhood experiences on depression (Model 5) (i.e., the first stage of the mediating processes) to be moderated by physical activity. Including interaction terms with physical activity in Equation 3 allowed the effect of depression (i.e., the second stage of the mediating processes) and the residual effect of adverse childhood experiences on functional dependence (Model 6) to be moderated by physical activity.
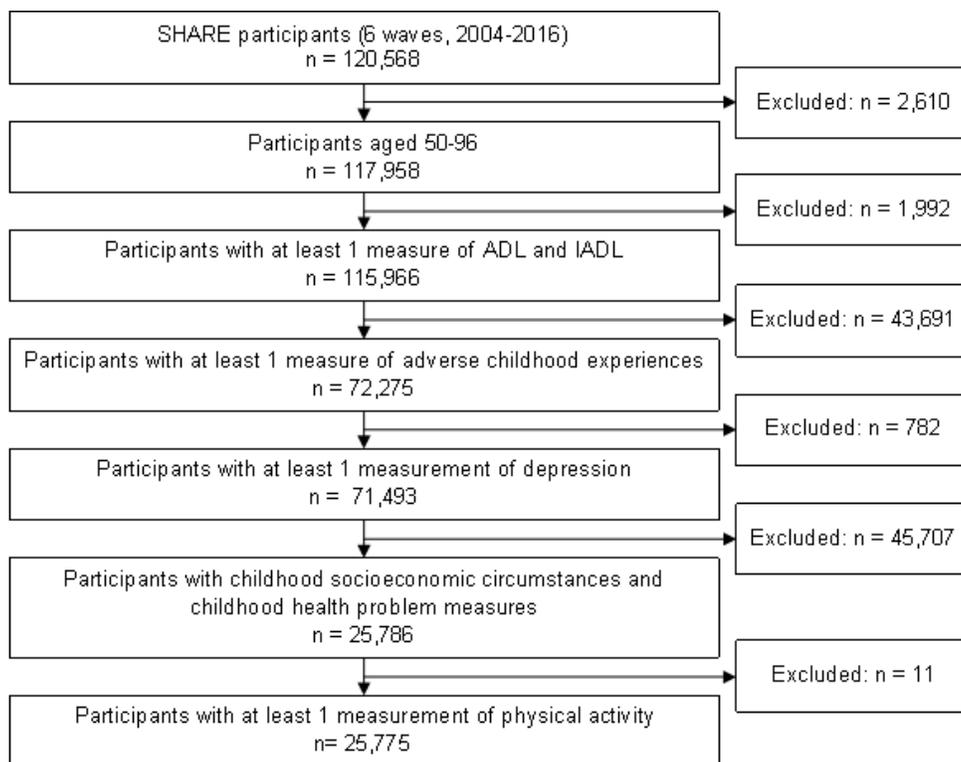

Figure 1. **Flow diagram.**

3. RESULTS

3.1. Descriptive results

The dataset included a total of 25,775 participants, aged 62±9 years (mean±SD), living in 14 European countries, with a depression score of 2.3±2.2, 14,342 women (55.6%), 18,080 physically active participants (70.1%), 20,263 participants (78.6%) without adverse childhood experience, 4,526 (17.6%) with 1 adverse childhood experience, and 986 (3.8%) with 2 or more childhood adverse experiences. The flow diagram is reported in Figure 1.

3.2. Effects of adverse childhood experiences on functional dependence

3.2.1. Mediation by depression

3.2.1.1. ADL

Model 1 (Equation 1) showed a graded association between the number of adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of functional limitations in ADL (bs = .040, .067, $ps = 6 \times 10^{-6}$, 1×10^{-4}, 95% CIs [.023, .057], [.033, .101], respectively; Figure 2, left panel). Model 2 (Equation 2) showed an association between the number of adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of depressive symptoms in older age (bs = .361, .599, $ps < 2 \times 10^{-16}$, 95% CIs [.307, .415], [.492, .705], respectively; Figure 2, middle panel). Model 3 (Equation 3) showed that a larger number of depressive symptoms was associated with a larger number of limitations in ADL (b = .057, $p < 2 \times 10^{-16}$, 95% CIs [.082, .087]; Figure 2, right panel). Model 3 also showed that the graded association between the number of adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of functional limitations in ADL became weaker with the addition of depression (bs = .019, .033, ps = .023, .048, 95% CIs [.003, .036], [2×10^{-4}, .067], respectively; Figure 2, left panel). From model 1 to 3, these associations decreased by 51% (0 vs. 1 adverse childhood experience) and 50% (0 vs. ≥2 adverse childhood experiences). Taken together, these results demonstrate that depression mediated the association between adverse childhood experiences and functional dependence in ADL.
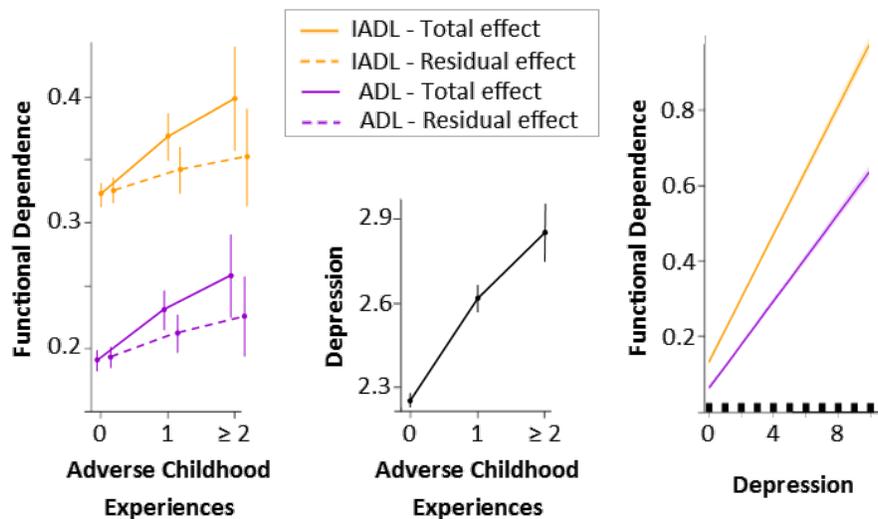

Figure 2. **Main effects and 95% confidence interval demonstrating that depression mediates the association between adverse childhood experiences and functional dependence in activities of daily living (ADL; orange) and instrumental activities of daily living (IADL; purple).** Solid lines illustrate the effect of adverse childhood experiences when the mediator (depression) is not in the equation (total effect). Dashed lines illustrate the effect of adverse childhood experiences when depression is in the equation (residual effect).

3.2.1.2. IADL

Model 1 showed a graded association between the number of adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of functional limitations in ADL (bs = .046, .076, $ps = 2 \times 10^{-5}$, 4×10^{-4}, 95% CIs [.025,

.067], [.034, .117], respectively; Figure 2, left panel). Model 2 was the same as for ADL (Figure 2, middle panel). Model 3 showed that a larger number of depressive symptoms was associated with a larger number of limitations in IADL (b = .085, $p < 2 \times 10^{-16}$, 95% CIs [.082, .087]; Figure 2, right panel). Model 3 also showed that the graded association between the number of adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of functional limitations in IADL became non-significant with the addition of depression (bs = .016, .027, ps = .119, .184, 95% CIs [-.004, .036], [-.013, .067], respectively; Figure 2, left panel). From model 1 to 3, these associations decreased by 65% (0 vs. 1 adverse childhood experience) and 64% (0 vs. ≥2 adverse childhood experiences). Taken together, these results demonstrate that depression mediated the association between adverse childhood experiences and functional dependence in IADL.
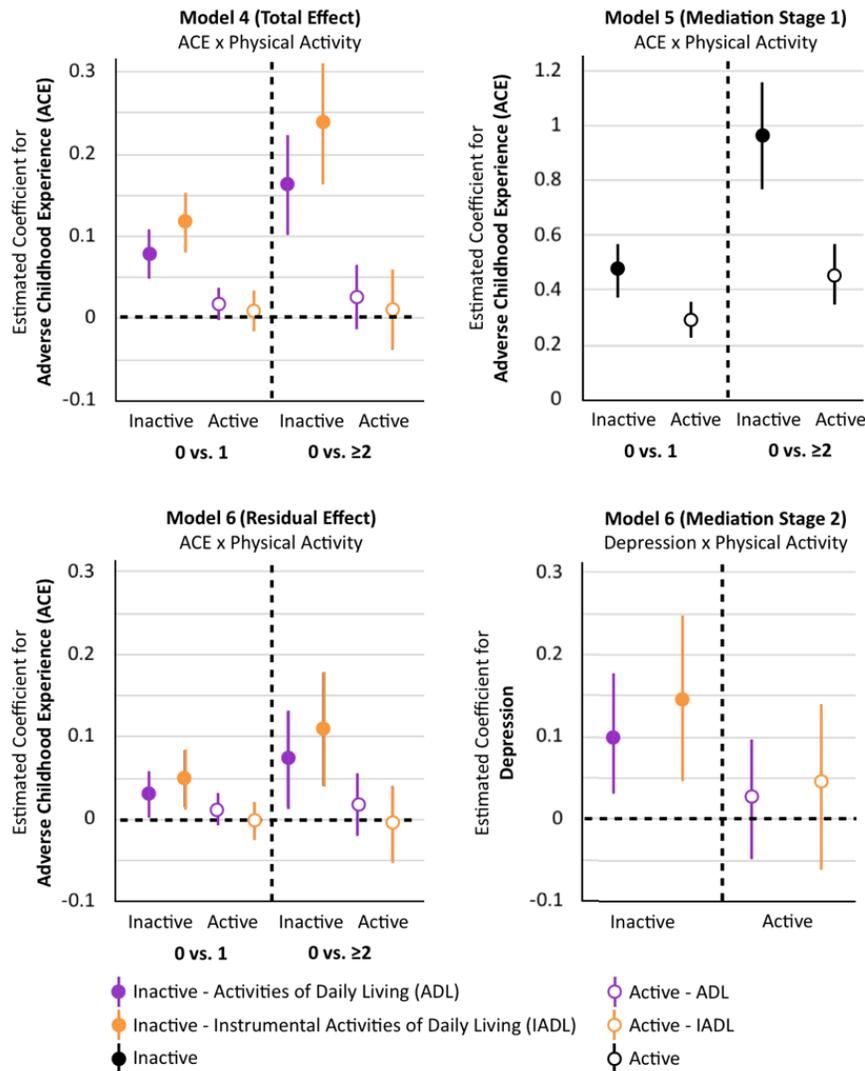

Figure 3. **Conditional b coefficients and 95% confidence interval as a function of physical activity.** The upper-left panel illustrates how physical activity moderates the total effect of adverse childhood experiences (0 vs. 1 and 0 vs. ≥2 adverse childhood experiences) on functional dependence. The upper-right panel illustrates how physical activity moderates the first stage of the mediation by depression. The lower-left panel illustrates the absence of moderation by physical activity on the residual effect of adverse childhood experiences on activities of daily living (ADL) and the moderation effect on this effect on instrumental activities of daily living (IADL). The lower-right panel illustrates how physical activity moderates the second stage of the mediation. Functional dependence in ADL and IADL are in orange and purple, respectively. Physically inactive and active participants are illustrated by filled and empty circles, respectively.

3.2.2. Moderation by physical activity

3.2.2.1. ADL

Model 4 showed a graded moderation of the association between adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and functional dependence in ADL by physical activity (bs = -.060, -.135, ps = .001, 2×10^{-4}, 95% CIs [-.096, -.024], [-.207, -.063], respectively; Figure 3A, left panel). Model 5 showed a graded moderation of the association between adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and the number of depressive syndromes by physical activity (bs = -.179, -.515, ps = .002, 9×10^{-6}, 95% CIs [-.292, -.065], [-.742, -.288], respectively; Figure 3A, central panel). Model 6 showed a moderation of the association between depression and functional dependence in ADL by physical activity (b = -.073, $p < 2\times10^{-16}$, 95% CIs [-.077, -.069]; Figure 3A, right panel). Model 6 also showed that the graded moderation of the association between adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and functional dependence in ADL by physical activity became non-significant (bs = -.018, -.055, ps = .306, .116, 95% CIs [-.053, .016], [-.124, .014], respectively). From model 4 to 6, these moderations decreased by 70% (0 vs. 1 adverse childhood experience) and 59% (0 vs. ≥2 adverse childhood experiences). Taken together these results demonstrate a mediated moderation (Muller et al., 2015; Figure 4). Figure 3 revealed that the effects of adverse childhood experiences (left panel) and depression (right panel) on functional dependence in ADL (purple in the figure) were not significant in physically active participants (ps > .081) as the 95% confidence interval crossed the zero line.

3.2.2.2. IADL

Model 4 showed a graded moderation of the association between adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and functional dependence in IADL by physical activity (bs = -.109, -.227, ps = 1×10^{-6}, 4×10^{-7}, 95% CIs [-.153, -.065], [-.315, -.140], respectively; Figure 3B, left panel). Model 5 was the same as for ADL. Model 6 showed a moderation of the association between depression and functional dependence in IADL by physical activity (b = -.100, $p < 2\times10^{-16}$, 95% CIs [-.106, -.095]; Figure 3B, right panel). Model 6 also showed that the graded moderation of the association between adverse childhood experiences (0 vs. 1, 0 vs. ≥2) and functional dependence in IADL by physical activity became weaker (bs = -.052, -.114, ps = .014, .007, 95% CIs [-.197, -.010], [-.093, -.032], respectively). From model 4 to 6, these moderations decreased by 53% (0 vs. 1 adverse childhood experience) and 50% (0 vs. ≥2 adverse childhood experiences). Taken together these results demonstrate a mediated moderation (Muller et al., 2015) (Figure 4). Figure 3 revealed that the effects of adverse childhood experiences (left panel) and depression (right panel) on functional dependence in IADL (orange in the figure) were not significant in physically active participants (ps > .528).

4. DISCUSSION

4.1. Main findings

This study uncovered three main findings. For the first time, we show that depression mediates the effect of adverse childhood experiences on functional dependence in older age. Second, results showed that physical activity reduced the effect of adverse childhood experiences on depression and on the residual effect on IADL. Third, results revealed that adverse childhood experiences were not (directly or indirectly) associated with functional dependence (ADL or IADL) in physically active individuals.

4.2. Comparison with previous studies

Our results showing that adverse childhood experiences are associated with functional dependence is consistent with previous literature (Laditka and Laditka, 2018; Amemiya et al., 2018). The effect of adverse childhood experiences is consistent with etiological models for depression considering stressful experiences as depression triggers (Monroe and Simons, 1991) and with previous results showing an association between adverse childhood experiences and the probability of depressive disorders (Chapman et al., 2004; Angelini et al., 2016). The effect of depression on functional dependence supports previous studies showing an association between depression and functional dependence (Braune and Berger, 2005; Ormel et al., 1994; Shrira and Litwin, 2014; Wada et al., 2005). The mechanisms underlying this association could lie in the main symptom of depression, the "lack of interest to all or most things" (Rosenström and Jokela, 2017),

which can potentially decrease the frequency an individual engages in ADL and IADL. In the long term, this decreased frequency could impact the ability to perform these activities, especially in aging, by further increasing the age-related decline of movement control such as postural balance (Boisgontier et al., 2017) and bimanual coordination (Maes et al., 2017). The protective effect of physical activity is in line with multiple studies, especially those showing that physical activity reduces the risk of developing depression (Chekroud et al., 2018) and decreases functional dependence (Tak et al., 2013).
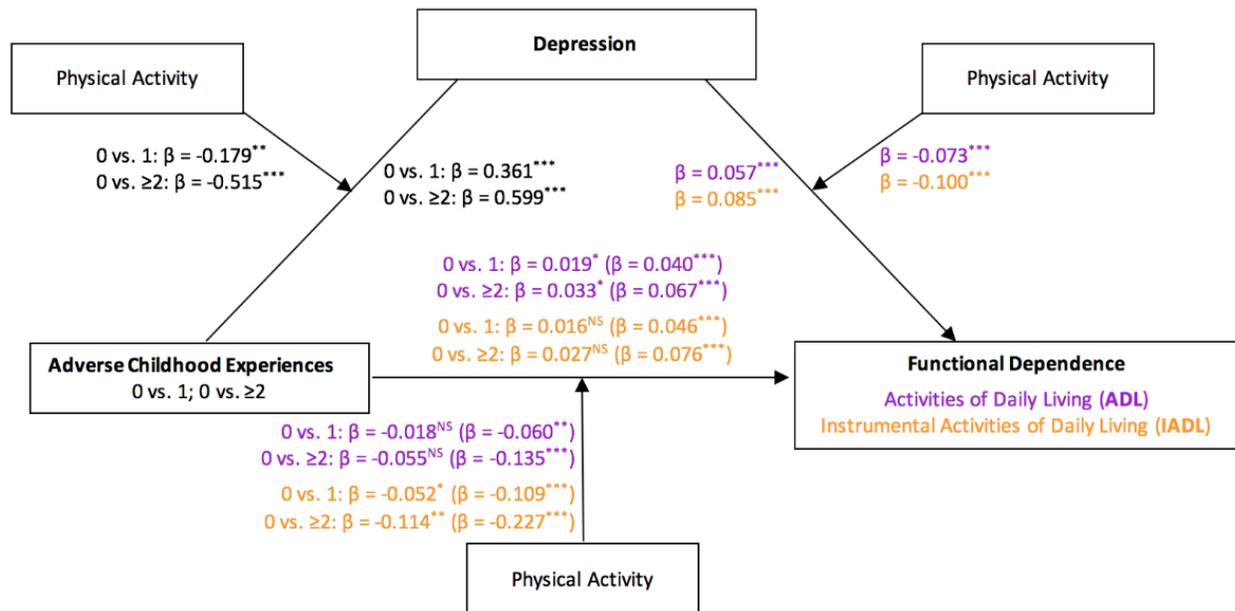
Figure 4. **Mediated moderation of the effect of adverse childhood experiences on functional dependence.** βs in brackets are the coefficients when the mediator is not in the equation (total effect). βs not in brackets are the coefficients when the mediator (depression) and covariates are in the equation (residual effect). Results related to functional dependence in activities of daily living (ADL) and instrumental activities of daily living (IADL) are in purple and orange, respectively.

4.3. Strengths and limitations

This study has many strengths. The sample is large and includes non-institutionalized older adults from multiple European countries. Moreover, we used a validated measure of depression (EURO-D), two different indicators of functional dependence that consistently showed that same pattern of results based on sophisticated statistical analyses suited to examine, for the first time, a potential mechanism of moderated mediation between adverse childhood experiences, depression, functional dependence, and physical activity. However, three potential limitations should be noted. First, there is the potential for recall bias as adverse childhood experiences were based on self-reports. Yet, the validity of these self-reports has been demonstrated (Hardt and Rutter, 2004). Second, although two widely validated measures of functional dependence were used and revealed consistent results, these measures were self-reported. Future studies should investigate whether our results apply to objective indicators of functional dependence (e.g., walking speed, chair stand, balance). There is the potential for misclassification bias regarding physical activity. However, the likelihood of this bias is small because we used a very conservative definition of physical activity.

4.4. Conclusion

Physical activity cancels the negative impact of adverse childhood experiences on functional dependence. In inactive individuals, the effect of adverse childhood experiences on functional dependence (ADL and IADL) is mediated by depression.

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AUTHOR CONTRIBUTIONS

MPB conceived the study. SC, SS managed the data. MPB, BC analyzed the data. MPB, BC drafted the manuscript. DO prepared the code to make it suitable for open repositories. All authors contributed to the improvement of the manuscript.

PREPRINT AGREEMENT

All authors are aware of and have agreed to submission of this manuscript as a preprint.

DATA AND CODE SHARING

The SHARE dataset is freely available at http://www.share-project.org/data-access.html. The code is available on GitHub (https://github.com/matthieuboisgontier/SHARE_ACE_FunctionalDependence) and will soon be published in Zenodo and get a DOI.

COMPETING INTERESTS

All authors declare no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

ETHICAL APPROVAL

This study was part of the SHARE study, approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

TRANSPARENCY

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned have been explained.

SUPPLEMENTAL MATERIAL

Childhood socioeconomic circumstances

Childhood socioeconomic circumstances were determined according to the index of childhood circumstances (Wahrendorf and Blane, 2015) combining 4 binary indicators reflecting specific childhood socioeconomic circumstances of participants at the age of 10: occupational position of the main breadwinner, number of books at home, housing overcrowding, and housing quality. The occupational position of the main breadwinner was built based on a reclassification of the 10 main occupational groups of the International Standard Classification of Occupations (ISCO) according to their skill levels (Wahrendorf et al., 2013). The first and second levels were grouped into the "disadvantaged" occupational position and the third and fourth levels were grouped into the "advantaged" occupational position. A binary item was built for the number of books at home, with the category "0–10 books" an indicator of social disadvantage. Overcrowding (i.e., more than 1 person per room lived in the housing) was constructed based on information related to the number of people living in the housing and number of rooms in the house (excluding kitchen, bathrooms, and hallways). Quality of the housing was assessed by the presence of a fixed bath, cold running water supply, hot running water supply, inside toilet, and central heating. If none of these were present, the housing was coded as "disadvantaged". By combining the information for these 4 indicators, we computed a 5-level categorical variable of "most advantaged", "advantaged", "middle", "disadvantaged", and "most disadvantaged" childhood socioeconomic circumstances.

Childhood health problems

Childhood health problems were long hospitalisation (i.e., hospitalization for one month or more before the age of 15), multiple hospitalizations (i.e., more than three times within a 12-month period before the age of 15), childhood illness (e.g., polio, asthma, meningitis, encephalitis), and childhood serious health conditions (severe headaches, psychiatric problem, fractures, heart trouble, cancers, and physical injury that has led to permanent handicap, disability or limitation in daily life). By combining the information for these five indicators, we computed a two-level categorical variable of participants with no childhood health problems (i.e., participants who answered "no" to all categories filled out) and participants with one or more childhood health problems (i.e., participants who answered "yes" to at least one category filled out).

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