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Supplementary information

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Physical activity for public health in the 21st century

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1. Country-level results of global domain-specific socioeconomic and gender-based physical activity inequalities

In total, 68 countries were included (9 High-income, 16 Upper middle-income, 28 lower middle-income and 15 low-income countries). Supplementary tables show the country, year of data collection, World Bank income category, the prevalence of meeting WHO physical activity guidelines through active leisure (Supplementary Table 1), active transport (Supplementary Table 2), and active labour (Supplementary Table 3), and the respective absolute difference or SII at a national level.

Supplementary Table 1. Prevalence of Meeting WHO physical activity guidelines through active leisure, and gender and socioeconomic inequalities.

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Afghanistan	2018	LIC	12·3 (9·7, 15·5)	19·8 (15·3, 24·3)	36·0 (25·0, 47·1)
Algeria	2016	UMIC	13·7 (12·5, 14·9)	18·5 (16·5, 20·5)	21·1 (17·9, 24·4)
Armenia	2016	LMIC	9·2 (7·6, 11·1)	4·0 (0·5, 7·6)	15·5 (7·4, 23·6)
Azerbaijan	2017	UMIC	18·3 (15·9, 21·1)	5·7 (1·6, 9·9)	9·6 (1·7, 17·4)
Bahamas	2011	HIC	25·7 (14·9, 40·5)	9·0 (0·2, 17·9)	12·9 (2·2, 23·5)
Bangladesh	2018	LMIC	9·1 (8·0, 10·4)	12·5 (10·1, 14·9)	22·2 (17·5, 26·9)
Barbados	2007	HIC	27·0 (22·9, 31·6)	10·5 (5·3, 15·6)	29·5 (19·3, 39·7)
Belarus	2016	UMIC	19·5 (17·1, 22·2)	6·9 (3·9, 9·9)	14·5 (8·3, 20·7)
Benin	2015	LIC	16·4 (13·4, 19·8)	11·7 (8·0, 15·5)	28·5 (21·3, 35·8)
Botswana	2014	UMIC	25·5 (22·7, 28·5)	24·9 (19·8, 30·0)	21·4 (12·7, 30·1)
British Virgin Islands	2009	HIC	29·8 (28·7, 30·9)	7·1 (1·5, 12·7)	22·6 (16·1, 29·1)
Brunei Darussalam	2015	HIC	41·1 (38·8, 43·5)	29·2 (25·1, 33·4)	16·5 (8·9, 24·1)
Bhutan	2014	LMIC	21·6 (18·1, 25·5)	24·7 (18·6, 30·8)	36·2 (27·9, 44·5)
Cabo Verde	2007	LMIC	26·9 (19·8, 35·4)	27·0 (14·1, 40·0)	42·5 (34·5, 50·5)
Cambodia	2010	LIC	8·8 (7·6, 10·1)	7·0 (4·9, 9·1)	18·0 (13·7, 22·2)
Cayman Islands	2012	HIC	41·9 (40·7, 43·0)	13·5 (1·6, 25·4)	40·5 (27·7, 53·3)
Comoros	2011	LIC	12·9 (11·5, 14·4)	16·0 (13·4, 18·5)	24·9 (20·3, 29·6)
Ecuador	2018	UMIC	27·6 (23·8, 31·9)	23·8 (20·6, 26·9)	33·4 (27·3, 39·5)
Eritrea	2010	LIC	2·0 (1·5, 2·7)	4·5 (2·8, 6·2)	6·1 (3·3, 8·9)
Eswatini	2014	LMIC	26·7 (24·3, 29·3)	31·2 (26·3, 36·1)	29·6 (21·3, 38·0)
Ethiopia	2015	LIC	4·6 (3·8, 5·6)	6·0 (4·3, 7·6)	15·4 (11·8, 18·9)
Fiji	2011	LMIC	34·3 (31·0, 37·8)	22·2 (18·0, 26·5)	29·3 (22·3, 36·3)
French Polynesia	2010	HIC	44·0 (41·6, 46·4)	23·7 (19·6, 27·9)	27·5 (19·6, 35·5)
Gabon	2009	UMIC	26·7 (22·2, 31·6)	27·3 (23·2, 31·4)	24·2 (15·6, 32·9)
Gambia	2010	LIC	12·2 (10·1, 14·6)	20·6 (17·1, 24·2)	37·0 (31·7, 42·3)
Georgia	2016	LMIC	7·8 (6·6, 9·3)	8·5 (5·9, 11·2)	5·6 (0·4, 10·8)
Grenada	2010	UMIC	25·7 (21·2, 30·9)	16·5 (10·1, 22·8)	23·9 (14·0, 33·8)
Guinea	2009	LIC	18·4 (15·7, 21·4)	27·4 (22·9, 32·0)	46·1 (38·0, 54·1)
Guyana	2016	UMIC	21·1 (18·5, 23·9)	22·1 (17·9, 26·3)	12·7 (3·9, 21·4)
Iraq	2015	UMIC	14·7 (13·0, 16·6)	19·3 (16·0, 22·7)	23·8 (17·7, 29·9)
Kenya	2015	LMIC	15·9 (13·7, 18·4)	15·4 (11·6, 19·2)	22·4 (15·7, 29·0)
Kiribati	2015	LMIC	15·4 (13·0, 18·0)	14·2 (9·1, 19·3)	12·5 (-0·5, 25·4)
Kuwait	2014	HIC	25·5 (24·0, 27·0)	15·4 (12·5, 18·4)	9·8 (4·6, 15·1)
Kyrgyzstan	2013	LMIC	9·3 (7·1, 12·1)	12·5 (8·1, 16·8)	15·8 (3·6, 27·9)

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Lao	2013	LMIC	14·3 (11·6, 17·4)	9·1 (5·4, 12·8)	14·7 (6·6, 22·8)
Lebanon	2017	UMIC	12·8 (9·6, 16·8)	9·7 (4·4, 14·9)	29·8 (18·1, 41·5)
Lesotho	2012	LMIC	26·1 (21·9, 30·7)	16·7 (11·5, 21·8)	2·5 (-10·5, 15·6)
Liberia	2011	LIC	14·1 (12·2, 16·3)	14·0 (10·5, 17·4)	19·2 (12·9, 25·4)
Libya	2009	UMIC	19·8 (17·7, 22·0)	7·4 (3·7, 11·1)	10·4 (5·0, 15·8)
Malawi	2017	LIC	33·6 (29·5, 38·0)	24·5 (18·8, 30·2)	32·1 (19·2, 44·9)
Maldives	2011	UMIC	31·9 (29·3, 34·6)	27·3 (22.2, 32·4)	12·2 (2·5, 22·0)
Moldova	2013	LMIC	10·2 (8·7, 12·0)	8·5 (5·6, 11·4)	6·8 (0·8, 12·7)
Mongolia	2013	LMIC	48·7 (42·6, 54·9)	-3·6 (-9·9, 2·6)	-3·7 (-14·5, 7·2)
Morocco	2017	LMIC	12·0 (10·9, 13·3)	14·9 (12·6, 17·3)	33·5 (28·6, 38·4)
Myanmar	2014	LMIC	8·1 (6·2, 10·6)	8·1 (4·6, 11·7)	8·9 (0·8, 17·0)
Nauru	2015	HIC	26·9 (24·7, 29·3)	23·0 (18·1, 28·0)	-8·3 (-16·3, -0·3)
Nepal	2019	LMIC	15·4 (12·7, 18·5)	-16·8 (-21·1, -12·5)	31·9 (24·4, 39·4)
Pakistan	2013	LMIC	3·8 (3·2, 4·4)	7·0 (5·7, 8·2)	6·9 (4·8, 8·9)
Palau	2011	UMIC	39·1 (34·9, 43·3)	18·8 (14·0, 23·5)	11·3 (0·9, 21·7)
Qatar	2012	HIC	26·8 (24·4, 29·3)	21·9 (17·4, 26·5)	10·2 (3·3, 17·2)
Rwanda	2012	LIC	12·6 (11·4, 13·9)	18·4 (16·1, 20·7)	23·9 (19·2, 28·6)
Samoa	2013	LMIC	35·0 (31·9, 38·1)	15·4 (6·8, 24·0)	28·6 (16·1, 41·2)
Sao Tome & Principe	2008	LMIC	21·0 (17·5, 25·0)	25·0 (19·3, 30·6)	28·1 (20·0, 36·2)
Seychelles	2004	UMIC	25·8 (23·3, 28·5)	10·3 (5·1, 15·5)	29·7 (20·1, 39·2)
Sierra Leone	2009	LIC	7·2 (5·7, 9·1)	10·2 (7·8, 12·6)	17·9 (12·4, 23·5)
Solomon Islands	2015	LMIC	25·4 (22·5, 28·6)	22·2 (17·6, 26·9)	19·5 (9·8, 29·3)
Sri Lanka	2014	LMIC	10·1 (8·7, 11·8)	13·6 (10·9, 16·4)	15·7 (10·0, 21·5)
Sudan	2016	LMIC	21·8 (18·5, 25·6)	25·5 (20·9, 30·2)	12·5 (6·8, 18·3)
Tajikistan	2016	LMIC	18·7 (15·9, 21·8)	20·0 (15·4, 24·5)	18·6 (5·3, 32·0)
Tanzania	2012	LIC	22·0 (19·7, 24·5)	13·7 (9·0, 18·3)	14·0 (4·7, 23·4)
Timor-Leste	2014	LMIC	12·6 (10·6, 14·9)	14·7 (11·1, 18·2)	-18·8 (-61·9, 24·3)
Togo	2010	LIC	20·1 (17·6, 22·8)	19·8 (15·9, 23·8)	39·6 (31·5, 47·7)
Tonga	2017	UMIC	10·5 (8·6, 12·7)	10·4 (7·0, 13·8)	10·2 (5·1, 15·2)
Tuvalu	2015	UMIC	41·0 (35·7, 46·5)	36·1 (30·3, 42·0)	25·1 (15·3, 34·9)
Uganda	2014	LIC	19·3 (17·5, 21·3)	15·4 (11·9, 19·0)	24·2 (18·2, 30·2)
Vanuatu	2011	LMIC	33·1 (30·5, 35·9)	17·8 (14·2, 21·4)	7·9 (-2·6, 18·4)
Vietnam[e]	2015	LMIC	21·4 (19·5, 23·3)	10·0 (6·5, 13·4)	
Zambia	2017	LMIC	20·1 (18·3, 22·0)	21·1 (17·7, 24·5)	21·4 (15·5, 27·3)

[a] World Bank (WB) country-income categories, where LIC is low-income country, LMIC is lower middle-income country, UMIC is upper middle-income country, and HIC is high-income country.

[b] Percentage of the population meeting the WHO physical activity guidelines of 150 minutes per week or more, through leisure-time physical activity.

[c] Gender-based inequalities were calculated by estimating the absolute difference in percentage points between the prevalence of meeting WHO physical activity guidelines through leisure-time physical activity among men, and the prevalence of meeting WHO physical activity guidelines through leisure-time physical activity among women.

[d] Slope Index of Inequality (SII) denotes the absolute differences in predicted values (percentage points) between those with the highest versus lowest educational attainment (used as a proxy for socioeconomic status), taking into consideration the entire distribution of education in the population, by using a logistic regression model.

[e] The WHO STEPS dataset does not include data on educational attainment for Vietnam.

Supplementary Table 2. Prevalence of Meeting WHO physical activity guidelines through active transport, and gender and socioeconomic inequalities.

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Afghanistan	2018	LIC	39·6 (31·6, 48·2)	48·0 (40·3, 55·6)	39·7 (27·7, 51·7)
Algeria	2016	UMIC	53·4 (51·1, 55·8)	30·7 (27·7, 33·7)	12·3 (7·0, 17·5)
Armenia	2016	LMIC	57·6 (53·3, 61·8)	-4·3 (-10·0, 1·5)	3·7 (-7·6, 15·0)
Azerbaijan	2017	UMIC	67·9 (64·1, 71·4)	8·9 (4·4, 13·4)	3·6 (-5·0, 12·3)
Bahamas	2011	HIC	21·6 (19·2, 24·2)	5·1 (-3·2, 13·3)	-15·8 (-22·0, -9·7)
Bangladesh	2018	LMIC	43·0 (40·8, 45·3)	43·9 (39·2, 48·6)	-1·1 (-7·7, 5·6)
Barbados	2007	HIC	24·7 (20·8, 29·1)	3·5 (-3·2, 10·3)	-4·6 (-15·6, 6·3)
Belarus	2016	UMIC	72·9 (70·0, 75·7)	-6·3 (-9·3, -3·3)	-5·4 (-13·8, 3·0)
Benin	2015	LIC	60·7 (56·7, 64·5)	2·5 (-1·8, 6·9)	-4·8 (-15·6, 5·9)
Botswana	2014	UMIC	50·9 (47·5, 54·2)	13·9 (9·4, 18·4)	-22·6 (-31·8, -13·4)
British Virgin Islands	2009	HIC	20·5 (13·8, 29·4)	2·7 (-9·4, 14·8)	-8·4 (-20·4, 3·5)
Brunei Darussalam	2015	HIC	23·5 (21·3, 26·0)	4·0 (0·4, 7·6)	-3·9 (-11·2, 3·4)
Bhutan	2014	LMIC	49·2 (44·0, 54·3)	5·5 (-0·0, 11·1)	-1·6 (-12·6, 9·5)
Cabo Verde	2007	LMIC	54·0 (36·8, 70·3)	5·8 (-4·1, 15·8)	-34·9 (-44·2, -25·7)
Cambodia	2010	LIC	29·3 (27·2, 31·6)	1·8 (-1·3, 4·9)	-27·9 (-33·4, -22·4)
Cayman Islands	2012	HIC	20·7 (13·8, 29·9)	3·6 (-7·4, 14·5)	-17·1 (-26·3, -7·8)
Comoros	2011	LIC	72·6 (70·7, 74·4)	13·6 (10·6, 16·6)	-6·6 (-12·3, -0·8)
Ecuador	2018	UMIC	48·1 (45·1, 51·1)	5·5 (2·0, 9·0)	-16·6 (-24·3, -8·9)
Eritrea	2010	LIC	61·9 (57·8, 65·8)	15·8 (12·3, 19·3)	6·0 (-2·1, 14·1)
Eswatini	2014	LMIC	39·9 (37·3, 42·6)	15·1 (9·3, 21·0)	-3·2 (-12·3, 5·9)
Ethiopia	2015	LIC	49·5 (46·2, 52·8)	12·3 (9·3, 15·3)	-4·2 (-11·1, 2·8)
Fiji	2011	LMIC	42·7 (38·8, 46·6)	16·7 (12·4, 20·9)	9·8 (1·6, 18·0)
French Polynesia	2010	HIC	33·9 (31·1, 36·7)	8·5 (4·5, 12·6)	-19·3 (-27·4, -11·3)
Gabon	2009	UMIC	53·6 (50·2, 57·0)	18·6 (14·3, 22·9)	9·6 (-0·3, 19·5)
Gambia	2010	LIC	57·2 (49·9, 64·2)	11·3 (7·0, 15·6)	11·3 (-0·7, 23·3)
Georgia	2016	LMIC	68·0 (65·6, 70·4)	3·4 (-0·3, 7·0)	1·3 (-7·8, 10·4)
Grenada	2010	UMIC	37·3 (32·1, 42·7)	5·9 (-0·5, 12·3)	-5·0 (-17·7, 7·6)
Guinea	2009	LIC	81·0 (78·2, 83·6)	6·3 (2·0, 10·7)	-11·0 (-20·3, -1·8)
Guyana	2016	UMIC	36·2 (33·1, 39·3)	9·4 (3·6, 15·2)	-2·3 (-13·4, 8·9)
Iraq	2015	UMIC	27·8 (25·2, 30·6)	22·9 (18·8, 27·0)	11·5 (3·9, 19·0)
Kenya	2015	LMIC	58·6 (55·5, 61·6)	6·7 (1·6, 11·8)	-11·2 (-20·7, -1·7)
Kiribati	2015	LMIC	32·3 (25·6, 39·8)	9·8 (-0·4, 20·1)	-4·1 (-19·1, 11·0)
Kuwait	2014	HIC	8·0 (7·1, 9·0)	7·2 (5·3, 9·1)	4·5 (1·0, 8·0)
Kyrgyzstan	2013	LMIC	67·1 (63·6, 70·5)	6·2 (-1·0, 13·4)	11·8 (0·0, 23·6)
Lao	2013	LMIC	49·0 (44·6, 53·4)	3·8 (-5·8, 13·5)	-32·5 (-43·8, -21·2)
Lebanon	2017	UMIC	28·1 (22·8, 34·1)	-5·2 (-13·3, 2·9)	23·5 (9·2, 37·9)
Lesotho	2012	LMIC	60·7 (56·4, 64·8)	16·8 (10·3, 23·4)	-34·9 (-44·9, -24·9)
Liberia	2011	LIC	50·3 (44·9, 55·7)	5·0 (1·0, 9·1)	-10·1 (-23·9, 3·7)
Libya	2009	UMIC	32·2 (29·4, 35·0)	25·1 (21·6, 28·6)	2·6 (-5·3, 10·5)
Malawi	2017	LIC	72·5 (69·0, 75·8)	14·9 (9·9, 19·9)	-6·8 (-16·6, 2·9)
Maldives	2011	UMIC	32·5 (30·0, 35·2)	-7·1 (-12.3, - 2·0)	-20·4 (-30·3, -10·5)
Moldova	2013	LMIC	76·2 (74·0, 78·3)	-5·7 (-9·3, -2·0)	-2·6 (-9·7, 4·5)

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Mongolia	2013	LMIC	47·3 (44·0, 50·7)	-0·8 (-4·8, 3·2)	-6·6 (-20·0, 6·9)
Morocco	2017	LMIC	61·0 (59·5, 62·4)	16·2 (13·3, 19·1)	-0·2 (-5·5, 5·2)
Myanmar	2014	LMIC	53·1 (42·8, 63·1)	4·2 (1·2, 7·2)	-21·4 (-29·9, -12·9)
Nauru	2015	HIC	18·5 (14·8, 22·8)	8·0 (2·4, 13·6)	10·4 (3·2, 17·5)
Nepal	2019	LMIC	73·0 (68·4, 77·1)	-2·9 (-7·5, 1·7)	-5·8 (-15·6, 3·9)
Pakistan	2013	LMIC	51·9 (49·3, 54·5)	30·1 (26·9, 33·4)	-16·5 (-23·5, -9·5)
Palau	2011	UMIC	25·7 (22·0, 29·9)	5·7 (-0·8, 12·2)	-7·9 (-16·8, 1·0)
Qatar	2012	HIC	41·3 (37·5, 45·2)	13·3 (6·8, 19·7)	1·3 (-6·2, 8·7)
Rwanda	2012	LIC	74·0 (72·0, 75·9)	8·9 (6·5, 11·2)	-2·0 (-8·0, 3·9)
Samoa	2013	LMIC	58·5 (51·7, 65·0)	5·3 (-0·8, 11·4)	3·7 (-12·5, 19·8)
Sao Tome and Principe	2008	LMIC	52·7 (48·5, 56·8)	13·8 (10·6, 17·1)	-7·0 (-14·8, 0·8)
Seychelles	2004	UMIC	36·9 (34·2, 39·8)	-6·5 (-12·1, -0·9)	-0·1 (-10·8, 10·6)
Sierra Leone	2009	LIC	58·2 (50·5, 65·6)	6·2 (-0·9, 13·2)	1·6 (-15·0, 18·2)
Solomon Islands	2015	LMIC	38·9 (35·2, 42·8)	8·2 (3·8, 12·7)	-5·1 (-17·1, 6·8)
Sri Lanka	2014	LMIC	32·5 (30·2, 34·8)	11·2 (8·0, 14·3)	-19·6 (-25·8, -13·4)
Sudan	2016	LMIC	48·8 (43·8, 53·8)	18·5 (12·1, 24·8)	-4·8 (-14·2, 4·7)
Tajikistan	2016	LMIC	53·9 (49·7, 58·1)	19·2 (12·8, 25·7)	7·0 (-8·1, 22·1)
Tanzania	2012	LIC	67·2 (64·4, 69·8)	15·4 (10·8, 19·9)	-15·2 (-26·3, -4·0)
Timor Leste	2014	LMIC	16·2 (12·1, 21·3)	-14·5 (-35·0, 6·1)	9·8 (-4·5, 24·0)
Togo	2010	LIC	77·3 (74·7, 79·6)	3·5 (-0·1, 7·1)	-17·3 (-24·9, -9·8)
Tonga	2017	UMIC	32·7 (29·3, 36·3)	8·8 (3·6, 14·1)	-9·2 (-19·9, 1·6)
Tuvalu	2015	UMIC	36·8 (28·1, 46·4)	13·1 (4·2, 22·1)	-9·9 (-16·8, -3·0)
Uganda	2014	LIC	67·2 (64·8, 69·6)	3·4 (-0·4, 7·2)	-4·2 (-12·0, 3·6)
Vanuatu	2011	LMIC	52·5 (50·0, 55·0)	12·7 (8·7, 16·7)	-20·9 (-29·3, -12·5)
Vietnam[e]	2015	LMIC	28·0 (24·8, 31·5)	-7·2 (-10·7, -3·8)	
Zambia	2017	LMIC	58·4 (56·0, 60·7)	18·3 (14·3, 22·4)	-9·0 (-16·7, -1·3)

[a] World Bank (WB) country-income categories, where LIC is low-income country, LMIC is lower middle-income country, UMIC is upper middle-income country, and HIC is high-income country.

[b] Percentage of the population meeting the WHO physical activity guidelines of 150 minutes per week or more, through transport-based physical activity.

[c] Gender-based inequalities were calculated by estimating the absolute difference in percentage points between the prevalence of meeting WHO physical activity guidelines through transport-based physical activity among men, and the prevalence of meeting WHO physical activity guidelines through transport-based physical activity among women.

[d] Slope Index of Inequality (SII) denotes the absolute differences in predicted values (percentage points) between those with the highest versus lowest educational attainment (used as a proxy for socioeconomic status), taking into consideration the entire distribution of education in the population, by using a logistic regression model.

[e] The WHO STEPS dataset does not include data on educational attainment for Vietnam.

Supplementary Table 3. Prevalence of Meeting WHO physical activity guidelines through active labour, and gender and socioeconomic inequalities.

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Afghanistan	2018	LIC	58·4 (50·6, 65·7)	9·3 (-5·2, 23·7)	6·3 (-6·3, 18·9)
Algeria	2016	UMIC	43·8 (41·1, 46·6)	4·1 (0·6, 7·5)	-15·9 (-21·8, -10·0)
Armenia	2016	LMIC	48·7 (44·8, 52·7)	2·1 (-4·4, 8·7)	-15·4 (-27·5, -3·4)
Azerbaijan	2017	UMIC	49·6 (45·5, 53·8)	-2·3 (-7·6, 3·0)	-24·1 (-33·7, -14·5)
Bahamas	2011	HIC	36·3 (20·3, 56·0)	27·8 (7·1, 48·5)	-18·5 (-40·7, 3·7)
Bangladesh	2018	LMIC	75·4 (73·5, 77·3)	-10·0 (-14·1, -5·9)	-17·4 (-23·3, -11·6)
Barbados	2007	HIC	26·9 (20·7, 34·0)	17·8 (12·9, 22·7)	1·3 (-11·6, 14·2)
Belarus	2016	UMIC	42·9 (40·3, 45·5)	18·4 (14·9, 21·8)	-24·1 (-31·1, -17·1)
Benin	2015	LIC	64·0 (59·5, 68·2)	8·5 (4·2, 12·7)	-7·2 (-18·2, 3·8)
Botswana	2014	UMIC	47·0 (43·3, 50·8)	7·0 (1·3, 12·7)	-17·0 (-27·4, -6·6)
British Virgin Islands	2009	HIC	57·6 (47·6, 67·1)	20·1 (13·6, 26·6)	-36·2 (-39·9, -32·5)
Brunei Darussalam	2015	HIC	44·5 (41·6, 47·4)	6·8 (1·7, 11·9)	-17·0 (-23·9, -10·1)
Bhutan	2014	LMIC	83·2 (80·4, 85·7)	3·3 (-1·7, 8·3)	-30·7 (-38·5, -22·9)
Cabo Verde	2007	LMIC	61·3 (36·6, 81·4)	7·6 (-3·9, 19·1)	-15·7 (-40·6, 9·3)
Cambodia	2010	LIC	86·8 (85·1, 88·3)	0·9 (-1·6, 3·4)	-6·8 (-12·3, -1·4)
Cayman Islands	2012	HIC	43·2 (39·2, 47·3)	19·3 (8·6, 30·0)	-34·7 (-43·5, -25·8)
Comoros	2011	LIC	55·8 (53·6, 58·0)	15·2 (11·8, 18·7)	-17·4 (-24·0, -10·8)
Ecuador	2018	UMIC	54·7 (51·0, 58·4)	9·8 (3·5, 16·1)	-28·6 (-35·5, -21·6)
Eritrea	2010	LIC	75·8 (71·7, 79·4)	7·2 (3·7, 10·7)	-3·4 (-15·2, 8·3)
Eswatini	2014	LMIC	57·7 (52·6, 62·7)	4·4 (-1·4, 10·2)	-29·7 (-39·1, -20·2)
Ethiopia	2015	LIC	88·5 (87·2, 89·7)	4·9 (2·8, 7·1)	-6·0 (-10·2, -1·7)
Fiji	2011	LMIC	68·5 (64·5, 72·2)	16·2 (11·3, 21·0)	-2·3 (-10·5, 5·9)
French Polynesia	2010	HIC	63·0 (60·0, 65·8)	2·9 (-1·3, 7·0)	-30·2 (-38·3, -22·0)
Gabon	2009	UMIC	44·6 (39·0, 50·2)	9·8 (5·4, 14·3)	-11·3 (-23·7, 1·1)
Gambia	2010	LIC	68·1 (59·9, 75·2)	-0·4 (-6·6, 5·8)	-21·6 (-31·7, -11·5)
Georgia	2016	LMIC	52·5 (49·5, 55·4)	1·4 (-3·1, 5·9)	-34·2 (-42·4, -26·0)
Grenada	2010	UMIC	54·4 (48·8, 59·9)	19·1 (12·4, 25·7)	-0·6 (-11·8, 10·6)
Guinea	2009	LIC	53·2 (49·0, 57·3)	15·2 (8·8, 21·6)	-26·1 (-39·8, -12·3)
Guyana	2016	UMIC	52·4 (49·8, 54·9)	19·2 (14·6, 23·9)	-12·6 (-22·8, -2·3)
Iraq	2015	UMIC	27·8 (25·1, 30·7)	4·6 (0·6, 8·7)	-5·8 (-13·1, 1·4)
Kenya	2015	LMIC	81·1 (78·2, 83·8)	-4·1 (-9·8, 1·6)	-9·9 (-20·3, 0·4)
Kiribati	2015	LMIC	44·0 (39·4, 48·8)	22·2 (11·7, 32·7)	-5·1 (-27·2, 17·1)
Kuwait	2014	HIC	13·3 (12·2, 14·5)	9·3 (7·0, 11·6)	12·2 (7·9, 16·5)
Kyrgyzstan	2013	LMIC	64·2 (58·6, 69·4)	11·3 (6·5, 16·2)	-27·9 (-41·6, -14·1)
Lao	2013	LMIC	83·0 (79·3, 86·1)	13·4 (9·0, 17·8)	-20·4 (-27·9, -12·9)
Lebanon	2017	UMIC	11·4 (8·5, 15·2)	6·6 (0·7, 12·4)	-2·2 (-11·6, 7·1)
Lesotho	2012	LMIC	85·3 (82·3, 87·9)	-3·0 (-8·4, 2·4)	-13·5 (-22·4, -4·6)
Liberia	2011	LIC	52·3 (47·3, 57·3)	1·8 (-2·4, 5·9)	-20·2 (-35·5, -4·9)
Libya	2009	UMIC	37·9 (34·4, 41·6)	-4·9 (-10·7, 0·9)	-10·8 (-16·9, -4·6)
Malawi	2017	LIC	95·9 (94·6, 96·9)	0·1 (-1·8, 2·0)	-5·9 (-10·6, -1·2)
Maldives	2011	UMIC	15·5 (13·5, 17·6)	11·0 (6.9, 15·2)	-10·5 (-19·5, -1·6)
Moldova	2013	LMIC	55·4 (52·1, 58·7)	6·7 (2·9, 10·4)	-2·6 (-11·2, 5·9)

Country	Year	WB Country-Income Category[a]	Prevalence[b] (95%CI)	Gender-based inequality[c] (95%CI)	SII for socioeconomic inequality[d] (95%CI)
Mongolia	2013	LMIC	46·0 (38·7, 53·5)	8·9 (5·2, 12·7)	-26·6 (-43·2, -10·1)
Morocco	2017	LMIC	49·6 (48·1, 51·1)	-2·5 (-5·5, 0·6)	-13·2 (-18·6, -7·7)
Myanmar	2014	LMIC	69·0 (64·5, 73·1)	9·1 (5·8, 12·5)	-22·3 (-35·4, -9·2)
Nauru	2015	HIC	41·1 (35·1, 47·3)	11·8 (6·0, 17·7)	3·5 (-13·3, 20·3)
Nepal	2019	LMIC	80·2 (75·4, 84·2)	9·4 (5·2, 13·6)	-6·7 (-16·4, 3·0)
Pakistan	2013	LMIC	25·9 (23·7, 28·3)	15·7 (12·9, 18·5)	-21·6 (-28·2, -15·0)
Palau	2011	UMIC	51·2 (45·0, 57·4)	13·9 (8·3, 19·5)	-14·0 (-26·6, -1·5)
Qatar	2012	HIC	26·6 (23·0, 30·5)	5·0 (-0·8, 10·9)	-10·5 (-19·7, -1·4)
Rwanda	2012	LIC	57·1 (54·0, 60·2)	3·5 (0·6, 6·4)	-23·8 (-30·2, -17·5)
Samoa	2013	LMIC	68·3 (66·0, 70·5)	13·8 (2·2, 25·4)	0·8 (-12·7, 14·3)
Sao Tome and Principe	2008	LMIC	75·2 (64·7, 83·4)	10·1 (0·9, 19·3)	-3·8 (-11·6, 4·0)
Seychelles	2004	UMIC	56·6 (53·7, 59·5)	-1·9 (-7·7, 3·9)	-36·0 (-45·8, -26·2)
Sierra Leone	2009	LIC	77·6 (71·7, 82·6)	4·3 (-1·5, 10·1)	-22·4 (-33·9, -10·9)
Solomon Islands	2015	LMIC	70·1 (66·5, 73·4)	11·6 (6·5, 16·6)	-17·9 (-26·5, -9·4)
Sri Lanka	2014	LMIC	55·1 (52·4, 57·7)	14·3 (10·5, 18·0)	-27·9 (-35·1, -20·6)
Sudan	2016	LMIC	66·7 (60·9, 72·1)	-3·9 (-8·4, 0·5)	-25·2 (-31·2, -19·3)
Tajikistan	2016	LMIC	29·5 (25·2, 34·2)	12·9 (6·7, 19·1)	-7·9 (-21·6, 5·8)
Tanzania	2012	LIC	88·6 (85·7, 91·0)	-0·8 (-3·7, 2·0)	-7·8 (-16·0, 0·3)
Timor-Leste	2014	LMIC	78·2 (61·4, 89·0)	11·4 (5·5, 17·3)	-37·4 (-42·8, -32·0)
Togo	2010	LIC	71·2 (66·8, 75·3)	1·2 (-2·8, 5·3)	-23·2 (-33·1, -13·2)
Tonga	2017	UMIC	37·7 (30·4, 45·7)	10·2 (3·3, 17·2)	-17·3 (-25·4, -9·1)
Tuvalu	2015	UMIC	55·5 (46·2, 64·3)	18·4 (13·0, 23·7)	-7·4 (-20·2, 5·3)
Uganda	2014	LIC	88·1 (86·4, 89·6)	0·8 (-2·5, 4·1)	-16·1 (-21·5, -10·7)
Vanuatu	2011	LMIC	88·3 (86·4, 90·0)	1·9 (-0·4, 4·2)	-18·1 (-24·6, -11·6)
Vietnam[e]	2015	LMIC	49·5 (44·5, 54·6)	16·6 (12·2, 21·0)	
Zambia	2017	LMIC	74·8 (72·5, 77·0)	6·2 (2·9, 9·6)	-26·6 (-32·9, -20·4)

[a] World Bank (WB) country-income categories, where LIC is low-income country, LMIC is lower middle-income country, UMIC is upper middle-income country, and HIC is high-income country.

[b] Percentage of the population meeting the WHO physical activity guidelines of 150 minutes per week or more, through occupational physical activity.

[c] Gender-based inequalities were calculated by estimating the absolute difference in percentage points between the prevalence of meeting WHO physical activity guidelines through occupational physical activity among men, and the prevalence of meeting WHO physical activity guidelines through occupational physical activity among women.

[d] Slope Index of Inequality (SII) denotes the absolute differences in predicted values (percentage points) between those with the highest versus lowest educational attainment (used as a proxy for socioeconomic status), taking into consideration the entire distribution of education in the population, by using a logistic regression model.

[e] The WHO STEPS dataset does not include data on educational attainment for Vietnam.

Supplementary Table 4. Country-specific estimates of domain-specific physical activity inequalities by gender and socioeconomic status.

	Active Leisure		Active transport		Active labour	
Country (year of data collection)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)
Low-income countries						
Afghanistan (2018)	19·8 (15·3, 24·3) ♀	36·0 (25·0, 47·1) ↓	48·0 (40·3, 55·6) ♀	39·7 (27·7, 51·7) ↓	3 9· (-5·2, 23·7) ≈	6·3 (-6·3, 18·9) ≈
Benin (2015)	11·7 (8·0, 15·5) ♀	28·5 (21·3, 35·8) ↓	2·5 (-1·8, 6·9) ≈	-4·8 (-15·6, 5·9) ≈	8·5 (4·2, 12·7) ♀	-7·2 (-18·2, 3·8) ≈
Cambodia (2010)	7·0 (4·9, 9·1) ♀	18·0 (13·7, 22·2) ↓	1·8 (-1·3, 4·9) ≈	-27·9 (-33·4, -22·4) ≈	0·9 (-1·6, 3·4) ≈	-6·8 (-12·3, -1·4) ↑
Comoros (2011)	16·0 (13·4, 18·5) ♀	24·9 (20·3, 29·6) ↓	13·6 (10·6, 16·6) ♀	-6·6 (-12·3, -0·8) ↑	15·2 (11·8, 18·7) ♀	-17·4 (-24·0, -10·8) ↑
Eritrea (2010)	4·5 (2·8, 6·2) ♀	6·1 (3·3, 8·9) ↓	15·8 (12·3, 19·3) ♀	6·0 (-2·1, 14·1) ≈	7·2 (3·7, 10·7) ♀	-3·4 (-15·2, 8·3) ≈
Ethiopia (2015)	6·0 (4·3, 7·6) ♀	15·4 (11·8, 18·9) ↓	12·3 (9·3, 15·3) ♀	-4·2 (-11·1, 2·8) ≈	4·9 (2·8, 7·1) ♀	-6·0 (-10·2, -1·7) ↑
Gambia (2010)	20·6 (17·1, 24·2) ♀	37·0 (31·7, 42·3) ↓	11·3 (7·0, 15·6) ♀	11·3 (-0·7, 23·3) ≈	-0·4 (-6·6, 5·8) ≈	-21·6 (-31·7, -11·5) ↑
Guinea (2009)	27·4 (22·9, 32·0) ♀	46·1 (38·0, 54·1) ↓	6·3 (2·0, 10·7) ♀	-11·0 (-20·3, -1·8) ↑	15·2 (8·8, 21·6) ♀	-26·1 (-39·8, -12·3) ↑
Liberia (2011)	14·0 (10·5, 17·4) ♀	19·2 (12·9, 25·4) ↓	5·0 (1·0, 9·1) ♀	-10·1 (-23·9, 3·7) ≈	1·8 (-2·4, 5·9) ≈	-20·2 (-35·5, -4·9) ↑
Malawi (2017)	24·5 (18·8, 30·2) ♀	32·1 (19·2, 44·9) ↓	14·9 (9·9, 19·9) ♀	-6·8 (-16·6, 2·9) ≈	0·1 (-1·8, 2·0) ≈	-5·9 (-10·6, -1·2) ↑
Rwanda (2012)	18·4 (16·1, 20·7) ♀	23·9 (19·2, 28·6) ↓	8·9 (6·5, 11·2) ♀	-2·0 (-8·0, 3·9) ≈	3·5 (0·6, 6·4) ♀	-23·8 (-30·2, -17·5) ↑
Sierra Leone (2009)	10·2 (7·8, 12·6) ♀	17·9 (12·4, 23·5) ↓	6·2 (-0·9, 13·2) ≈	1·6 (-15·0, 18·2) ≈	4·3 (-1·5, 10·1) ≈	-22·4 (-33·9, -10·9) ↑
Tanzania (2012)	13·7 (9·0, 18·3) ♀	14·0 (4·7, 23·4) ↓	15·4 (10·8, 19·9) ♀	-15·2 (-26·3, -4·0) ↑	-0·8 (-3·7, 2·0) ≈	-7·8 (-16·0, 0·3) ≈
Togo (2010)	19·8 (15·9, 23·8) ♀	39·6 (31·5, 47·7) ↓	3·5 (-0·1, 7·1) ≈	-17·3 (-24·9, -9·8) ↑	1·2 (-2·8, 5·3) ≈	-23·2 (-33·1, -13·2) ↑

Country (year of data collection)	Active Leisure: Gender-based inequality[a] (95%CI)		Active Leisure: Socioeconomic inequality[b] (95%CI)		Active transport: Gender-based inequality[a] (95%CI)		Active transport: Socioeconomic inequality[b] (95%CI)		Active labour: Gender-based inequality[a] (95%CI)		Active labour: Socioeconomic inequality[b] (95%CI)	
Uganda (2014)	15·4 (11·9, 19·0)	♀	24·2 (18·2, 30·2)	↓	3·4 (-0·4, 7·2)	≈	-4·2 (-12·0, 3·6)	≈	0·8 (-2·5, 4·1)	≈	-16·1 (-21·5, -10·7)	↑
Lower middle-income countries												
Armenia (2016)	4·0 (0·5, 7·6)	♀	15·5 (7·4, 23·6)	↓	-4·3 (-10·0, 1·5)	≈	3·7 (-7·6, 15·0)	≈	2·1 (-4·4, 8·7)	♀	-15·4 (-27·5, -3·4)	↑
Bangladesh (2018)	12·5 (10·1, 14·9)	♀	22·2 (17·5, 26·9)	↓	43·9 (39·2, 48·6)	♀	-1·1 (-7·7, 5·6)	≈	-10·0 (-14·1, -5·9)	≈	-17·4 (-23·3, -11·6)	↑
Buthan (2014)	24·7 (18·6, 30·8)	♀	36·2 (27·9, 44·5)	↓	5·5 (-0·0, 11·1)	≈	-1·6 (-12·6, 9·5)	≈	3·3 (-1·7, 8·3)	≈	-30·7 (-38·5, -22·9)	↑
Cabo Verde (2007)	27·0 (14·1, 40·0)	♀	42·5 (34·5, 50·5)	↓	5·8 (-4·1, 15·8)	≈	-34·9 (-44·2, -25·7)	↑	7·6 (-3·9, 19·1)	≈	-15·7 (-40·6, 9·3)	≈
Eswatini (2014)	31·2 (26·3, 36·1)	♀	29·6 (21·3, 38·0)	↓	15·1 (9·3, 21·0)	♀	-3·2 (-12·3, 5·9)	≈	4·4 (-1·4, 10·2)	≈	-29·7 (-39·1, -20·2)	↑
Fiji (2011)	22·2 (18·0, 26·5)	♀	29·3 (22·3, 36·3)	↓	16·7 (12·4, 20·9)	♀	9·8 (1·6, 18·0)	↓	16·2 (11·3, 21·0)	♀	-2·3 (-10·5, 5·9)	≈
Georgia (2016)	8·5 (5·9, 11·2)	♀	5·6 (0·4, 10·8)	↓	3·4 (-0·3, 7·0)	≈	1·3 (-7·8, 10·4)	≈	1·4 (-3·1, 5·9)	≈	-34·2 (-42·4, -26·0)	↑
Kenya (2015)	15·4 (11·6, 19·2)	♀	22·4 (15·7, 29·0)	↓	6·7 (1·6, 11·8)	♀	-11·2 (-20·7, -1·7)	↑	-4·1 (-9·8, 1·6)	≈	-9·9 (-20·3, 0·4)	≈
Kiribati (2015)	14·2 (9·1, 19·3)	♀	12·5 (-0·5, 25·4)	≈	9·8 (-0·4, 20·1)	≈	-4·1 (-19·1, 11·0)	≈	22·2 (11·7, 32·7)	♀	-5·1 (-27·2, 17·1)	≈
Kyrgyzstan (2013)	12·5 (8·1, 16·8)	♀	15·8 (3·6, 27·9)	↓	6·2 (-1·0, 13·4)	≈	11·8 (0·0, 23·6)	≈	11·3 (6·5, 16·2)	♀	-27·9 (-41·6, -14·1)	↑
Lao (2013)	9·1 (5·4, 12·8)	♀	14·7 (6·6, 22·8)	↓	3·8 (-5·8, 13·5)	≈	-32·5 (-43·8, -21·2)	↑	13·4 (9·0, 17·8)	♀	-20·4 (-27·9, -12·9)	↑
Lesotho (2012)	16·7 (11·5, 21·8)	♀	2·5 (-10·5, 15·6)	≈	16·8 (10·3, 23·4)	♀	-34·9 (-44·9, -24·9)	↑	-3·0 (-8·4, 2·4)	≈	-13·5 (-22·4, -4·6)	↑
Moldova (2013)	8·5 (5·6, 11·4)	♀	6·8 (0·8, 12·7)	↓	-5·7 (-9·3, -2·0)	♂	-2·6 (-9·7, 4·5)	≈	6·7 (2·9, 10·4)	♀	-2·6 (-11·2, 5·9)	≈
Mongolia (2013)	-3·6 (-9·9, 2·6)	≈	-3·7 (-14·5, 7·2)	≈	-0·8 (-4·8, 3·2)	≈	-6·6 (-20·0, 6·9)	≈	8·9 (5·2, 12·7)	♀	-26·6 (-43·2, -10·1)	↑

	Active Leisure		Active transport		Active labour	
Country (year of data collection)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)
Morocco (2017)	14·9 (12·6, 17·3) ♀	33·5 (28·6, 38·4) ↓	16·2 (13·3, 19·1) ♀	-0·2 (-5·5, 5·2) ≈	-2·5 (-5·5, 0·6) ≈	-13·2 (-18·6, -7·7) ↑
Myanmar (2014)	8·1 (4·6, 11·7) ♀	8·9 (0·8, 17·0) ↓	4·2 (1·2, 7·2) ♀	-21·4 (-29·9, -12·9) ↑	9·1 (5·8, 12·5) ♀	-22·3 (-35·4, -9·2) ↑
Nepal (2019)	-16·8 (-21·1, -12·5) ♂	31·9 (24·4, 39·4) ↓	-2·9 (-7·5, 1·7) ≈	-5·8 (-15·6, 3·9) ≈	9·4 (5·2, 13·6) ♀	-6·7 (-16·4, 3·0) ≈
Pakistan (2013)	7·0 (5·7, 8·2) ♀	6·9 (4·8, 8·9) ↓	30·1 (26·9, 33·4) ♀	-16·5 (-23·5, -9·5) ↑	15·7 (12·9, 18·5) ♀	-21·6 (-28·2, -15·0) ↑
Samoa (2002)	15·4 (6·8, 24·0) ♀	28·6 (16·1, 41·2) ↓	5·3 (-0·8, 11·4) ≈	3·7 (-12·5, 19·8) ≈	13·8 (2·2, 25·4) ♀	0·8 (-12·7, 14·3) ≈
Sao Tome and Principe (2008)	25·0 (19·3, 30·6) ♀	28·1 (20·0, 36·2) ↓	13·8 (10·6, 17·1) ♀	-7·0 (-14·8, 0·8) ≈	10·1 (0·9, 19·3) ♀	-3·8 (-11·6, 4·0) ≈
Solomon Islands (2015)	22·2 (17·6, 26·9) ♀	19·5 (9·8, 29·3) ↓	8·2 (3·8, 12·7) ♀	-5·1 (-17·1, 6·8) ≈	11·6 (6·5, 16·6) ♀	-17·9 (-26·5, -9·4) ↑
Sri Lanka (2014)	13·6 (10·9, 16·4) ♀	15·7 (10·0, 21·5) ↓	11·2 (8·0, 14·3) ♀	-19·6 (-25·8, -13·4) ↑	14·3 (10·5, 18·0) ♀	-27·9 (-35·1, -20·6) ↑
Sudan (2016)	25·5 (20·9, 30·2) ♀	12·5 (6·8, 18·3) ↓	18·5 (12·1, 24·8) ♀	-4·8 (-14·2, 4·7) ≈	-3·9 (-8·4, 0·5) ≈	-25·2 (-31·2, -19·3) ↑
Tajikistan (2016)	20·0 (15·4, 24·5) ♀	18·6 (5·3, 32·0) ↓	19·2 (12·8, 25·7) ♀	7·0 (-8·1, 22·1) ≈	12·9 (6·7, 19·1) ♀	-7·9 (-21·6, 5·8) ≈
Timor Leste (2014)	14·7 (11·1, 18·2) ♀	-18·8 (-61·9, 24·3) ≈	-14·5 (-35·0, 6·1) ≈	9·8 (-4·5, 24·0) ≈	11·4 (5·5, 17·3) ♀	-37·4 (-42·8, -32·0) ↑
Vanuatu (2011)	17·8 (14·2, 21·4) ♀	7·9 (-2·6, 18·4) ≈	12·7 (8·7, 16·7) ♀	-20·9 (-29·3, -12·5) ↑	1·9 (-0·4, 4·2) ≈	-18·1 (-24·6, -11·6) ↑
Vietnam (2015)[c]	10·0 (6·5, 13·4) ♀		-7·2 (-10·7, -3·8) ♂		16·6 (12·2, 21·0) ♀	
Zambia (2017)	21·1 (17·7, 24·5) ♀	21·4 (15·5, 27·3) ↓	18·3 (14·3, 22·4) ♀	-9·0 (-16·7, -1·3) ↑	6·2 (2·9, 9·6) ♀	-26·6 (-32·9, -20·4) ↑

	Active Leisure		Active transport		Active labour	
Country (year of data collection)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)
Upper middle-income countries						
Algeria (2016)	18·5 (16·5, 20·5) ♀	21·1 (17·9, 24·4) ↓	30·7 (27·7, 33·7) ♀	12·3 (7·0, 17·5) ↓	4·1 (0·6, 7·5) ♀	-15·9 (-21·8, -10·0) ↑
Azerbaijan (2017)	5·7 (1·6, 9·9) ♀	9·6 (1·7, 17·4) ↓	8·9 (4·4, 13·4) ♀	3·6 (-5·0, 12·3) ≈	-2·3 (-7·6, 3·0) ≈	-24·1 (-33·7, -14·5) ↑
Belarus (2016)	6·9 (3·9, 9·9) ♀	14·5 (8·3, 20·7) ↓	-6·3 (-9·3, -3·3) ♂	-5·4 (-13·8, 3·0) ≈	18·4 (14·9, 21·8) ♀	-24·1 (-31·1, -17·1) ↑
Botswana (2014)	24·9 (19·8, 30·0) ♀	21·4 (12·7, 30·1) ↓	13·9 (9·4, 18·4) ♀	-22·6 (-31·8, -13·4) ↑	7·0 (1·3, 12·7) ♀	-17·0 (-27·4, -6·6) ↑
Ecuador (2018)	23·8 (20·6, 26·9) ♀	33·4 (27·3, 39·5) ↓	5·5 (2·0, 9·0) ♀	-16·6 (-24·3, -8·9) ↑	9·8 (3·5, 16·1) ♀	-28·6 (-35·5, -21·6) ↑
Gabon (2009)	27·3 (23·2, 31·4) ♀	24·2 (15·6, 32·9) ↓	18·6 (14·3, 22·9) ♀	9·6 (-0·3, 19·5) ≈	9·8 (5·4, 14·3) ♀	-11·3 (-23·7, 1·1) ≈
Grenada (2010)	16·5 (10·1, 22·8) ♀	23·9 (14·0, 33·8) ↓	5·9 (-0·5, 12·3) ≈	-5·0 (-17·7, 7·6) ≈	19·1 (12·4, 25·7) ♀	-0·6 (-11·8, 10·6) ≈
Guyana (2016)	22·1 (17·9, 26·3) ♀	12·7 (3·9, 21·4) ↓	9·4 (3·6, 15·2) ♀	-2·3 (-13·4, 8·9) ≈	19·2 (14·6, 23·9) ♀	-12·6 (-22·8, -2·3) ↑
Iraq (2015)	19·3 (16·0, 22·7) ♀	23·8 (17·7, 29·9) ↓	22·9 (18·8, 27·0) ♀	11·5 (3·9, 19·0) ↓	4·6 (0·6, 8·7) ♀	-5·8 (-13·1, 1·4) ≈
Lebanon (2017)	9·7 (4·4, 14·9) ♀	29·8 (18·1, 41·5) ↓	-5·2 (-13·3, 2·9) ≈	23·5 (9·2, 37·9) ↓	6·6 (0·7, 12·4) ♀	-2·2 (-11·6, 7·1) ≈
Libya (2009)	7·4 (3·7, 11·1) ♀	10·4 (5·0, 15·8) ↓	25·1 (21·6, 28·6) ♀	2·6 (-5·3, 10·5) ≈	-4·9 (-10·7, 0·9) ≈	-10·8 (-16·9, -4·6) ↑
Maldives (2011)	27·3 (22.2, 32·4) ♀	12·2 (2·5, 22·0) ↓	-7·1 (-12.3, - 2·0) ♂	-20·4 (-30·3, -10·5) ↑	11·0 (6.9, 15·2) ♀	-10·5 (-19·5, -1·6) ↑
Palau (2011)	18·8 (14·0, 23·5) ♀	11·3 (0·9, 21·7) ↓	5·7 (-0·8, 12·2) ≈	-7·9 (-16·8, 1·0) ≈	13·9 (8·3, 19·5) ♀	-14·0 (-26·6, -1·5) ↑
Seychelles (2004)	10·3 (5·1, 15·5) ♀	29·7 (20·1, 39·2) ↓	-6·5 (-12·1, -0·9) ♂	-0·1 (-10·8, 10·6) ≈	-1·9 (-7·7, 3·9) ≈	-36·0 (-45·8, -26·2) ↑
Tonga (2017)	10·4 (7·0, 13·8) ♀	10·2 (5·1, 15·2) ↓	8·8 (3·6, 14·1) ♀	-9·2 (-19·9, 1·6) ≈	10·2 (3·3, 17·2) ♀	-17·3 (-25·4, -9·1) ↑

	Active Leisure		Active transport		Active labour	
Country (year of data collection)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)	**Gender-based inequality**[a] (95%CI)	**Socioeconomic inequality**[b] (95%CI)
Tuvalu (2015)	36·1 (30·3, 42·0) ♀	25·1 (15·3, 34·9) ↓	13·1 (4·2, 22·1) ♀	-9·9 (-16·8, -3·0) ↑	18·4 (13·0, 23·7) ♀	-7·4 (-20·2, 5·3) ≈
High-income countries						
Bahamas (2011)	9·0 (0·2, 17·9) ♀	12·9 (2·2, 23·5) ↓	5·1 (-3·2, 13·3) ≈	-15·8 (-22·0, -9·7) ≈	27·8 (7·1, 48·5) ♀	-18·5 (-40·7, 3·7) ≈
Barbados (2007)	10·5 (5·3, 15·6) ♀	29·5 (19·3, 39·7) ↓	3·5 (-3·2, 10·3) ≈	-4·6 (-15·6, 6·3) ≈	17·8 (12·9, 22·7) ♀	1·3 (-11·6, 14·2) ≈
British Virgin Islands (2009)	7·1 (1·5, 12·7) ♀	22·6 (16·1, 29·1) ↓	2·7 (-9·4, 14·8) ≈	-8·4 (-20·4, 3·5) ≈	20·1 (13·6, 26·6) ♀	-36·2 (-39·9, -32·5) ↑
Brunei Darussalam (2015)	29·2 (25·1, 33·4) ♀	16·5 (8·9, 24·1) ↓	4·0 (0·4, 7·6) ♀	-3·9 (-11·2, 3·4) ≈	6·8 (1·7, 11·9) ♀	-17·0 (-23·9, -10·1) ↑
Cayman Islands (2012)	13·5 (1·6, 25·4) ♀	40·5 (27·7, 53·3) ↓	3·6 (-7·4, 14·5) ≈	-17·1 (-26·3, -7·8) ↑	19·3 (8·6, 30·0) ♀	-34·7 (-43·5, -25·8) ↑
French Polynesia (2010)	23·7 (19·6, 27·9) ♀	27·5 (19·6, 35·5) ↓	8·5 (4·5, 12·6) ♀	-19·3 (-27·4, -11·3) ↑	2·9 (-1·3, 7·0) ≈	-30·2 (-38·3, -22·0) ↑
Kuwait (2014)	15·4 (12·5, 18·4) ♀	9·8 (4·6, 15·1) ↓	7·2 (5·3, 9·1) ♀	4·5 (1·0, 8·0) ↓	9·3 (7·0, 11·6) ♀	12·2 (7·9, 16·5) ↓
Nauru (2015)	23·0 (18·1, 28·0) ♀	-8·3 (-16·3, -0·3) ↓	8·0 (2·4, 13·6) ♀	10·4 (3·2, 17·5) ↓	11·8 (6·0, 17·7) ♀	3·5 (-13·3, 20·3) ≈
Qatar (2012)	21·9 (17·4, 26·5) ♀	10·2 (3·3, 17·2) ↓	13·3 (6·8, 19·7) ♀	1·3 (-6·2, 8·7) ≈	5·0 (-0·8, 10·9) ≈	-10·5 (-19·7, -1·4) ↑

Supplementary Table 4 Legend:

[a] Gender-based inequalities were calculated by estimating the absolute difference in percentage points between the prevalence of meeting WHO physical activity guidelines through domain-specific physical activity among men versus women.

[b] Socioeconomic inequalities were calculated by estimating the Slope Index of Inequality, denoting the absolute differences in predicted values (percentage points) between those with the highest versus lowest educational attainment (used as a proxy for socioeconomic status), while taking into consideration the entire distribution of education in the population, by using a logistic regression model.

[c] The WHO STEPS dataset does not include data on educational attainment for Vietnam.

♀ Denotes that women have a lower prevalence of given domain-specific physical activity than men.

♂ Denotes that men have a lower prevalence of given domain-specific physical activity than women.

≈ Denotes similar or roughly equivalent prevalences across genders or socioeconomic strata.

↓ Denotes that those of lower socioeconomic status (assess as lower level of education) have a lower prevalence of given domain-specific physical activity than those of higher socioeconomic status.

↑ Denotes that those of higher socioeconomic status (assess as lower level of education) have a lower prevalence of given domain-specific physical activity than those of lower socioeconomic status.

Limitations

Despite the large number of countries included, representativeness of World Bank income groups is not expected due to the WHO STEPwise approach to surveillance data availability, and the necessary standardized data collection required for the harmonization process. The absence of representativeness of the World Bank income groups also motivated the presentation of unweighted median estimates, not accounting for different population sizes of each country. Furthermore, double stratification analysis was restricted the analysis to 48 countries due to small sample size of combined categories, reducing the generalization of the results. The implementation of an intersectionality lens is challenging in quantitative analysis. While the double stratification approach offers a straightforward interpretation of two important social identities addressed, the research field needs to advance to better explore an intersectionality framework seeking to understand other interwoven forms of marginalization that impact on physical activity, including race/ethnicity, gender identity/expression, disability, class, age, among others.[1,2]

2. Physical activity and immunity: biological pathways and mechanisms

A critical summary of the evidence on how physical activity enhances immunity through three key pathways: (1) increased immune surveillance, (2) immune system remodelling, and (3) inflammation reduction, was conducted. The first draft, and glossary, were prepared by RJS, and reviewed and edited by DS, EC, and UE. Supplementary Table 4 provides a glossary of immunology terms used in this section.

Supplementary Table 4. Glossary of basic immunology terms relevant for understanding the main pathways and mechanisms via which physical activity augments immunity.

Term	Definition
Antibodies	Special proteins produced by the immune system to help defend the body against harmful invaders like bacteria and viruses. They can bind to these invaders and mark them for destruction.
Antigen Presenting Cells	Cells that capture and display pieces of invaders (antigens) to the immune system. They act like informants, helping other immune cells recognize threats.
CD4 T Cells	A type of lymphocyte that assists in coordinating the immune response. They are important in helping the immune system recognize and destroy infected cells.
CD8 T Cells	A type of lymphocyte that directly targets and kills cells infected with viruses or other invaders.
Cytokines	Small hormone-like proteins produced by immune cells that act as messengers, helping to regulate and coordinate immune responses and inflammation.
Immune Depression	A state where the immune system is weakened or less effective, making the body more susceptible to infections and illnesses. This can happen due to various factors, including disease, stress, and certain medications. Immune depression can be reversible, whereas immune 'suppression' is considered chronic and long-lasting.
Leukocytes (White Blood Cells)	Blood cells that play a crucial role in the body's immune system. Neutrophils, lymphocytes, and monocytes are among the major subtypes of leukocytes. They help to identify and combat infections and diseases.
Myokines	Cytokines produced specifically by muscles during exercise that have various beneficial effects, including helping to coordinate immune responses and regulate metabolism and inflammation.
NK Cells (Natural Killer Cells)	A type of lymphocyte that can quickly recognize and attack infected or abnormal cells, including cancer cells.
Secondary Lymphoid Organs	Parts of the body where immune cells gather and interact to coordinate the immune response, such as the lymph nodes and the spleen.
Terminally Differentiated T Cells	T cells that have matured into specialized forms with specific functions. These cells are often highly effective at fighting infections but may have a limited lifespan. They are seen in greater frequency among older adults.

Physical Activity and Immune Surveillance

Immune surveillance refers to the body's natural defence mechanism, continuously monitoring and recognizing abnormal cells or foreign invaders, such as pathogens like viruses and bacteria. It achieves this through the continuous recirculation of immune cells and antibodies. When abnormalities are detected, these immune components work together to neutralize the threat. Physical activity is believed to protect against viruses and pathogens by enhancing the rate of immune surveillance.[3] A single bout of physical activity triggers the natural 'fight-or-flight' response, leading to an immediate increase in immune cells, particularly CD8+ T-cells and NK-cells, which are more effective at identifying and eliminating virus-infected cells. Additionally, antigen-presenting cells, such as monocytes, capable of recognizing viral proteins and presenting them to T-cells, are mobilized and redistributed with physical activity.[4]

Physical activity also results in a selective mobilization of 'memory' T-cells, which can respond to previously encountered viruses or vaccines, and 'naïve' T-cells, capable of recognizing and responding to new pathogens.[5] It promotes lymphatic flow and the transportation of antibodies necessary for neutralizing viruses and making them visible to T-cells.[5] After exercise, the mobilized cells surveil lymph nodes and peripheral tissues, including the lower and upper respiratory tracts.[6] Each bout of physical activity allows T-cells and antibodies to recirculate between the blood and tissues more frequently, increasing their chances of encountering infectious agents and vaccine antigens. This enhanced immune surveillance is thought to bolster protection against both novel and previously encountered pathogens, and may also explain how physical activity can enhance vaccine responses. Studies have indeed shown that single 20-30-minute exercise sessions of various intensities, performed just before vaccination, can enhance vaccine efficacy and immune responses to vaccine antigens, such as the COVID-19 vaccine.[7–9]

Skeletal muscle contraction during physical activity plays a pivotal role in improving host defense.[10] During single bouts of aerobic and resistance exercise, muscles release myokines, including interleukin-6 (IL-6) and IL-15, which facilitate movement of CD8+ T-cells and NK-cells to areas of infection. IL-15 also supports T-cell and NK-cell proliferation and their ability to kill infected cells, while IL-7 activates the thymus to produce new ‘naïve’ T-cells following resolution of viral infections or vaccination.[10] These myokines released during physical activity contribute to immune system maintenance and improvement of immune responses to infection and vaccination.

Physical Activity and Immune System Remodelling

Immune remodelling refers to the dynamic process of alterations within the immune system due to aging, stress or in response to infections. s people age, the immune system undergoes significant alterations, contributing to increased infection rates and reduced vaccine responses in older populations.[11] This process, known as immunosenescence, involves impairments in both the innate and adaptive immune systems. These impairments include reduced CD8+ T-cell and NK-cell killing capacity, decreased antibody quality and quantity, fewer naïve T-cells, a higher frequency of terminally differentiated inflammatory T-cells, and compromised migratory and antimicrobial functions of leukocytes. These changes often manifest in poor control of latent viral infections, indicating systemic immune system depression.[12] Physical activity is purported to have immune remodelling effects by promoting more ‘youthful’ immune phenotypes among middle-aged and older adults.[10]

Randomized controlled trials provide strong evidence that exercise training can positively remodel the immune system, increasing immune responses to vaccines, even in older individuals.[10,13,14] For instance, 12-months of moderate-intensity aerobic exercise training before receiving the trivalent influenza vaccine prolonged the duration of protective antibody levels in blood, compared to non-exercised controls.[13] Stronger antibody responses to the influenza vaccine after moderate-intensity exercise training have also been reported.[14] These improvements were partially attributed to psychosocial factors indicating possible direct and indirect (e.g., stress reduction) effects of exercise on immune modulation. Chronic stress has been shown to increase susceptibility to infection, aggravate lung inflammation, and promote latent viral reactivation.

Physical Activity and the Resolution of Inflammation

Aging, adiposity, and physical inactivity are major contributors to chronic low-grade inflammation, partly influenced by immunosenescence, which underlies numerous human diseases. Chronic inflammation places a burden on the immune system, reducing its ability to respond to new and persistent infections. This also leads to an exaggerated inflammatory response during infections, creating an ongoing cycle of inflammation known as a 'cytokine storm.' This cycle is challenging to resolve and can result in extensive tissue damage and even death. Physical activity can directly reduce chronic inflammation by altering the phenotype and function of inflammatory immune cells. Indirectly, it reduces highly inflammatory white adipose tissue, a significant component of visceral fat mass.[10]

Inhibiting chronic low-grade inflammation is likely a key mechanism by which physical activity helps protect against severe COVID-19, reducing the risk of hospitalization and death. Additionally, physical activity can expedite the resolution of inflammation following a viral infection. Moderate physical activity has been shown to improve survival in mice exposed to a lethal dose of influenza virus.[10] The lungs of infected mice exposed to physical activity had lower viral loads and fewer inflammatory cells, indicating that exercise contributed to reduced inflammation.[15] In the context of COVID-19, severe disease, hospitalizations, and deaths have been attributed to cytokine storms in the lungs, leading to fatal symptoms like acute respiratory distress syndrome, severe pneumonia, multiorgan failure, and coagulation issues.[16] Exercise is known to temper inflammation by directly acting on inflammatory pathways,[10] possibly explaining how physical activity can limit severe COVID-19 disease, as discussed earlier.

3. Epidemiological evidence of the effect of physical activity on COVID-19-related outcomes

Objective
To identify the most relevant epidemiological evidence of the associations between physical activity and COVID-19 related outcomes.

Methods
A narrative review of the literature on the epidemiological evidence for the effects of physical activity on COVID-19 related outcomes was conducted in two main stages: 1) search and identify high-quality existing reviews and meta-analyses, and then 2) supplement with original research articles published since the latest high-quality existing review.

Databases
Three investigators (IML, JT, EJS) independently searched PubMed/MEDLINE for peer-reviewed, systematic reviews and meta-analyses that examined the relationship of pre-COVID physical activity levels and COVID-19 related outcomes.

Language
We only searched for systematic reviews published in English.

Dates
No time or date restrictions were used during the search, but the search criteria, as defined by our search terms, helped ensured that only systematic review articles published within the context and timeline of the COVID-19 pandemic (i.e., as of 2020) were included. The search was last updated in August 2023.

Search Methodology
Outcomes of interest included COVID-19 infection, hospitalization / ICU, severity, post-COVID condition (PCC, “long COVID”, or post-acute sequelae of SARS-CoV-2 (PASC)), and related mortality.

The largest, most recent systematic review and meta-analysis identified at the time of the search was a meta-analysis of 16 studies of over 1·8 million individuals by Ezzatvar et al. The investigators searched for original articles published since the review using the same search terms as listed in Ezzatvar et al., augmenting the terms list with “long COVID”, “post-COVID condition (PCC)”, “post-acute sequelae of SARS-CoV-2 (PASC)”, and for articles that reference the Ezzatvar et al.

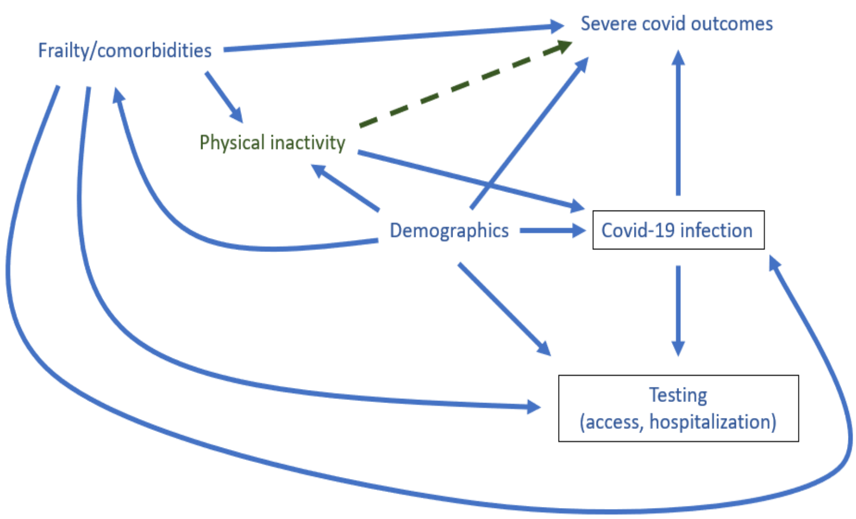
A critical examination of the evidence
Addressing the limitations discussed below through well-designed and implemented research strategies, including maximizing infrastructures to facilitate linkage of individual-level health data, social determinants, and test results across large, diverse, and unselected populations, will allow researchers to generate robust evidence on public health recommendations for physical activity, as well as other factors associated with decreased (increased) risk, in future pandemics.

<u>Study design</u>
The urgent need for rapid research necessitated leveraging existing cohort studies, surveillance/ ecological data, innovative study designs, and convenience samples. Studies linking participant information through administrative databases, can utilize existing data from diverse, large datasets with both historical and ongoing measures; however, linkages are time-consuming, prone to missing data, and require specialized techniques for data harmonization and analyses, a difficult task even under non-urgent conditions. For example, the UK Biobank, a large observational cohort study, quickly linked COVID-19 test results and COVID-related health outcome data to existing study information (including physical activity), allowing researchers to rapidly analyse the data rather than having to initiate an entirely new study. In another study from South Africa, researchers linked information on participant’s long-term physical activity from an online health and well-being community to data from a large medical plan with COVID-19 test results.[17]

Study participant selection – bias & generalisability
Convenience sampling of participants, such as those participating in established cohort studies, using a health app, who were tested, had a positive test result, and/or were hospitalized for COVID-19, was often employed to allow for rapid identification and recruitment of participants. However, this may lead to biased results. For example, a study among hospital patients may facilitate the collection of detailed information on people with serious complications, but the study would also oversample those with health conditions, characteristics, or demographic circumstances that increase the likelihood of being hospitalized. This bias is referred to as collider (or selection) bias which can attenuate, inflate, or even reverse the direction of the true association.[18]

Consider a study that examined the association between physical activity and risk of hospitalisation, ICU admission, and death after COVID-19 diagnosis in 48,440 adults registered with the Kaiser Permanente Southern California (United States) health plan.[19] Participants were eligible for this study if they were plan members, had information on physical activity in their charts, and tested positive or been diagnosed with COVID-19 between 1 January 2020 and 21 October 2020. However, because testing was not universally accessible then and participants admitted to hospitals were more likely to be tested, factors associated with testing or hospital admission 'collide' and may affect the results. Frailty or pre-existing comorbidities, which increase the risk of being hospitalized – and thus increase the probability of being tested and diagnosed – may make it harder to be physically active, which may affect COVID-19 severity and recovery. Online Supplementary Figure 1 shows a conceptual Directed Acyclic Graph demonstrating the possibility of collider bias in physical activity and severe COVID-19-outcome studies. Studies using probability-based participant recruitment with unrestricted access to testing can minimise such biases.

Supplementary Figure 1. Conceptual DAG demonstrating possibility of collider stratification bias influencing association between physical activity and severe covid-19 outcomes



Since both COVID-19 infection and testing are necessary to be included in the study (conditioned, in boxes), all variables associated with infection or testing, and the causes of the variables predicting infection or testing, could be associated due to collider bias. In the simplified DAG above, COVID-19 infection after exposure to SARS-CoV-2 can be caused by physical inactivity, demographic variables (age, sex, occupation, education, etc), or frailty/comorbidities. Thereby, individuals who were infected because of underlying frailty/comorbidities are less likely to have been infected because of physical inactivity, influencing the association between these two variables in subsequent analyses of severe covid-19 outcomes. Careful control for frailty/comorbidities and demographic conditions

would be necessary to remove this bias. Adapted from Griffith et al., 2020 - Collider bias undermines our understanding of COVID-19 disease risk and severity

Timing and period effects

An additional challenge for pandemics is that ascertainment of risk factors can be affected by events of a time-dependent nature, such as disease evolution, changes in disease case definition, population-level changes in behaviour, immunity levels, and disease prevalence, as well as changes in public health response (e.g., masking, and social distancing). Many of the early studies were centred around a single strain of COVID-19 virus; it remains unknown whether different strains influence the relationship between physical activity and COVID-19. Definitions of COVID-19 diagnosis and recovery have included the use of an oral / nasal swab, PCR, hospitalisations, and self-reported symptoms. Similarly, the definition of post-COVID-19 condition continues to evolve.

A related timing issue is when physical activity was assessed – if taking advantage of data already collected for other studies or purposes, the data may not be sufficiently proximal to the time of COVID-19 infection since it is unclear when timing of activity -chronic or acute- influences risk. For example, the UK Biobank collected physical activity data between 2006 and 2010, quite distant in time from the 2020 and later pandemic. It is possible to address this limitation by conducting further analyses which examine the stability of physical activity levels over time. In a study from South Korea, investigators conducted sensitivity analyses and showed similar associations using physical activity data collected at different times up to 5 years before the start of the pandemic.[20]

Supplementary Table 5 provides a summary of challenges and recommendations for improving physical activity research during future infectious disease emergencies.

Supplementary Table 5. Challenges and recommendations for strengthening the scientific evidence from epidemiologic studies of the role of physical activity and other risk/protective factors in COVID-19 and future pandemics.

Key Challenges	Description & Recommendations
Infrastructure / Rapid Response	Rapid (“real-time”), rigorous research studies are challenged by conventional funding timelines and protocols, which can take years.
	Accessible research infrastructure with dedicated funding, such as single or multiple linked health registries can be quickly utilized to study large, diverse, and unselected populations leveraging already collected demographic and related health information.
Selection Bias & Population Generalisability	Probability-based sampling of cases and comparison groups during circumstances with unrestricted access to testing and treatment are needed to circumvent risks of selection-bias and ensure generalizability of findings.
	Particular attention should be placed on including a diverse study population including equitable gender, race/ethnicity, age, socioeconomic circumstances, and geographic distribution.
Evolving Definitions, Prevalence, Variants / Mutations, Public Policy	Novel and rapidly developing conditions such as COVID-19 and other pandemics may not allow for previously established standardized data collection. Collection of data that allows evolving definitions / classification is encouraged.
	Changes in prevalence, disease variants / mutations, and other population-level factors (e.g., public policy) may limit consistency and generalizability across research studies and over time. Collection of information on these factors and subgroup analyses, when possible, may ameliorate these challenges.

4. Epidemiological evidence of the effect of physical of physical activity on depression

Objective
To identify and summarise the most relevant epidemiological evidence of the associations between physical activity and depression, including incident depression (i.e., examining preventive effects) and outcomes among individuals diagnosed with depression (i.e., examining treatment effects).

Methods
A summary (narrative review) of the literature on the epidemiological evidence for the effects of physical activity on clinical depression and depressive symptoms was conducted in three main stages: (1) we conducted a PubMed search using standardised search terms; (2) among search results, we identified a selection of recent, high-quality meta-analyses focused on general populations (vs. clinical populations, country-specific populations, etc.), including those restricted to (a) summarizing findings from RCTs (for studies examining physical activity as a treatment for depression), and from prospective cohort studies (for studies exploring physical activity as a preventive factor for developing depression); and, (3) we summarized key methods and takeaways from the selected recent, high-quality meta-analyses.

Databases
One investigator (DS) searched PubMed/MEDLINE for peer-reviewed, systematic reviews and meta-analyses that examined the relationship of physical activity and depression. DS and two additional investigators (JT and ES) helped identify the selection of recent, high-quality meta-analyses to highlight when summarising the state of the science.

Language
We only searched for systematic reviews published in English.

Dates
No time or date restrictions were used during the search. The search was last updated in May 2024.

Search Criteria
We searched for articles including:

- A “physical activity” term in the title.
- A “depression” term in the title.
- A “meta-analysis” term in the title.

Supplementary Table 6. Search terms used in review of reviews to assess changes in physical activity during COVID-19.

Physical Activity search terms	Depression terms	Meta-analysis terms
“physical activity” OR exercis*	depression OR “depressive symptoms”	Meta-analysis OR “meta analysis”

Results

PubMed/MEDLINE search results.
The initial search found 166 articles. After removing duplicates (n=1) and scanning the titles and abstracts to remove articles that were not a meta-analysis of the association between physical activity and depression outcomes (e.g., commentaries in response to a meta-analysis; meta-analyses of the effects of exercise on another outcome among patients with depression, etc.) (n=9), a final set of 156 unique meta-analysis papers was identified.

Key takeaways from systematic search

- Meta-analytic studies focused on:
    - Effects of overall MVPA or of leisure-time physical activity on depression or depressive symptoms.

  - Effects of exercise interventions on depression management or depressive symptom reduction.
  - Specific age groups.
  - Effects of PA or exercise on depression-related outcomes among clinical populations (e.g., people that have experienced stroke, cancer patients, patients with spinal cord injury, children with obesity, individuals with multiple sclerosis, individuals with COVID-19, etc.).
  - Effects of specific types of physical activities (e.g., walking, dancing, yoga) on depression and depressive symptoms.
  - Effects or aerobic vs. resistance training on depression or depressive symptoms.

- Most meta-analytic studies were about the treatment of depression outcomes with physical activity or exercise (vs. prevention), though there were also several meta-analyses summarising the preventive role of physical activity for depression.

- Among meta-analyses focused on the effect of physical activity as a treatment for depression, multiple meta-analyses are available that exclusively focused on summarising evidence from RCTs.

- Among meta-analyses focused on the effect of physical activity in preventing depression (with the outcome being incident depression), many meta-analyses combined multiple types of observational studies, and fewer were available restricted to prospective cohort observational studies (cohort) examining risk of incident depression.

Summary of findings
Of the meta-analyses found through the PubMed/MEDLINE search described above, we identified some as being highly relevant for this narrative review of the evidence, based on their time of publication (within <10 years), and methodology, including their inclusion criteria (restricting studies to RCTs only if studying treatment effects of physical activity on depression; or to prospective cohorts only if examining the association of physical activity with incident depression), as well as the authors' appraisal of the evidence with respect to quality and limitations of studies included in the meta-analysis.

Associations of physical activity with incident depression: summary of evidence from select meta-analyses

<u>Adults</u>

- In 2022, Pearce and colleagues published a meta-analysis summarizing findings from studies assessing the preventive effects of physical activity on incident depression among adults.[21] This meta-analysis only included studies using a prospective cohort design. Authors reported findings from 15 unique prospective cohort studies including more than 2 million person-years. Only studies with at least 3 years of follow-up were included. Authors reported an inverse curvilinear association between physical activity and incident depression, with greater differences in risk at lower levels of exposure. Among adults meeting WHO guidelines of physical activity (150 minutes per week of moderate- to vigorous-intensity physical activity), there was a lower risk of incident depression observed, compared to adults with no physical activity. Further, among adults that accumulated half of the WHO guidelines of physical activity, there was an observed 18% lower risk of depression (95% CI, 13%-23%), while those meeting guidelines had a 25% lower risk of incident depression compared to inactive adults (95%CI, 18%-32%). With respect to the quality of the studies and robustness of findings, including risk of bias and limitations, the authors reported that during follow up, proportions of men versus women, adjustment for co-morbidities or prevalent depression at baseline, and method of depression diagnosis, were not significantly associated with effect sizes, supporting robustness of findings. The authors of this harmonized meta-analysis attempted to reduce risk of bias from undiagnosed depression by restricting inclusion to studies with at least 3 years of follow-up. The authors of this harmonized meta-analysis underscore that given the recurrent nature of depression and physical activity participation, the use of repeated measures for the exposure (physical activity) would be particularly important for future studies, to avoid risk of reverse causality.

- In 2018, Schuch and colleagues published a meta-analysis summarizing findings of prospective cohort studies among depression-free participants at baseline.[22] Authors identified 49 unique prospective cohort studies with a pooled sample size of 266,939 participants. Authors examined studies for adults, older adults, and youth. Results reported for adults were consistent with those reported by Pearce and colleagues in 2022, such that physical activity was inversely associated with incident depression (OR=0·78, 95%CI, 0·70%, 0·87%). Authors reported no moderating effects by gender or other sociodemographic variables. The overall quality of studies included in this meta-analysis was deemed as being moderate to high according to the Newcastle-Ottawa Scale (score of 6·3), although authors note significant evidence of publication bias. However, their findings did not meaningfully change once adjusting for publication bias.

Older adults

- The aforementioned 2018 meta-analysis by Schuch and colleagues also included studies of older adults.[22] Consistent with what was found for adults, physical activity was found to be inversely associated with incident depression among older adults (OR=0·86, 95%CI, 0·75, 0·98). As was the case for adult studies summarized in this meta-analysis, no evidence of effect measure modification by gender or other sociodemographic variables was identified, and risk overall quality of studies included was deemed as being moderate to high, and findings remained robust after adjusting for possible publication bias (see above).

Adolescents and youth

- The aforementioned 2018 meta-analysis by Schuch and colleagues also included studies of adolescents and youth.[22] Consistent with what was found for adults and older adults, physical activity was found to be inversely associated with incident depression among adolescents and youth (OR=0·90, 95%CI, 0·83, 0·98). As was the case for adult and older adults studies summarized in this meta-analysis, no evidence of effect measure modification by gender or other sociodemographic variables was identified, and risk overall quality of studies included was deemed as being moderate to high, and findings remained robust after adjusting for possible publication bias (see expanded description of this meta-analysis under "Adults" section).

- In 2019, Biddle and colleagues published a review of reviews and meta-analysis examining evidence for causal effects of physical activity on mental health in children and adolescents, including several outcomes, one of which was incident depression.[23] The authors used Bradford Hill guidelines to assess causality, focusing on three specific criteria (strength of association, dose-response, and experimental evidence). The authors concluded that there is partial evidence for a causal association between physical activity and depression in adolescents and young adults.

Physical activity as a treatment for depression: summary of evidence from select meta-analyses

Adults

- In 2024, Noetel and colleagues published a meta-analysis of studies testing the effects of physical activity on depression among adults.[24] The main outcome of interest was depressive disorder management. This meta-analysis only included studies using an RCT design. Authors reported findings from 218 unique studies, representing 495 arms, and 14,170 participants. Compared to controls, authors reported moderate reductions in depression for walking or jogging (n=1210, κ=51, Hedges' g −0·62, 95% credible interval −0·80 to −0·45), yoga (n=1047, κ=33, g −0·55, −0·73 to −0·36), strength training (n=643, κ=22, g −0·49, −0·69 to −0·29), mixed aerobic exercises (n=1286, κ=51, g −0·43, −0·61 to −0·24), and tai chi or qigong (n=343, κ=12, g −0·42, −0·65 to

−0·21). Further, the authors concluded that the effects of physical activity on depression management were proportional to the intensity of physical activity prescribed. In terms of quality of the studies included, the authors report that findings appeared robust to publication bias. However, only one of the studies included in the meta-analysis met the Cochrane criteria for low risk of bias, resulting in low confidence. Despite limitations, the authors conclude that physical activity of many types (walking, jogging, strength training, yoga, etc.) are an effective treatment for depression among adults.

<u>Adolescents and youth</u>

- In 2018, Bailey and colleagues published a meta-analysis of studies testing the effects of physical activity on diagnosed or threshold depression among children and adolescents.[25] This meta-analysis only included studies using an RCT design. Authors reported findings from 16 RCTs and 771 participants. Comparted to controls, authors reported observing large effects of physical activity on depression symptoms (SMD = −0·82, 95% CI = −1·02 to −0·61, p < 0·05, I2 = 38%). Further, authors reported that the effect remained robust in trials with clinical samples (k = 5, SMD = −0·72, 95% CI = −1·15 to −0·30), and in trials using attention/activity placebo controls (k = 7, SMD = −0·82, 95% CI = −1·05 to −0·59).” In terms of quality of the studies included and risk of bias, authors reported low dropout rates across arms (11%), yet low level of evidence, given to trial-level risks of bias and suspected publication bias. These limitations suggest caution in the interpretation of the results. The authors conclude that physical activity appears to be a promising and acceptable treatment for children and youth experiencing depression.”

Limitations of the available evidence

The quality of many of the studies supporting the role of physical activity for the prevention and treatment of depression requires improvement.

Common issues found in the studies included in these meta-analysis, and which can increase the risk of bias, include:

- Lack of information on the blinding of participants and/or research personnel in RCTs examining the treatment effects of physical activity on depression management.
- Insufficient or lack of allocation concealment in RCTs examining the treatment effects of physical activity on depression management.
- Insufficient information on random sequence generation in RCTs examining treatment effects of physical activity on depression management.
- Use of a single assessment of the exposure (physical activity levels), at baseline, in cohort studies examining the possible preventive effects of physical activity on risk of incident depression, rather than repeated measures over time of the exposure.
- Inconsistent adjustment for potential confounders in prospective cohort studies assessing the role of physical activity as a preventive factor for incident depression.

Future research priorities

Although there is some evidence suggesting that physical activity can have comparable or larger efficacy in treating depression than established treatments, most research to date in this topic has not included direct comparisons. Studies employing modern RCT designs (e.g., sequential trials) are recommended to help understand if physical activity can be an effective stand-alone treatment for depression, which would be especially helpful for patients that cannot tolerate anti-depressive medication. Further, there is insufficient research on the effects of different physical activity domains in preventing depression. A majority of studies have either exclusively focused on the leisure domain, or have assessed overall physical activity (i.e., all domains). Understanding if active travel or active labour contribute have similar effects on incident depression would be important for populations were a large portion of physical activity is necessity driven. It is possible that necessity-driven physical activity has adverse mental health effects, but this warrants further study.

Limitations of the narrative review

As any narrative review process, ours may have issues related to completeness of the literature covered, interpretation of findings, and objectivity. Because this was not a complete systematic review, abstracting data from all meta-analyses found through the systematic PubMed/MEDLINE search, but rather, involved selecting a few articles to focus on, the information presented may exclude some evidence. In contrast to the epidemiological evidence linking physical activity with infectious disease outcomes, which became more robust only recently, as a result of research during COVID-19, the links between physical activity and depression have been explored extensively and since several decades ago. Because of this, we chose to focus on summarising key findings from some of the more recent, complete, and robust meta-analyses. The selection of which of the recent (<10 years) meta-analyses were "best" for summarising the evidence, however, inherently implied some subjectivity by the authors conducting the work. We tried to minimise inserting our own biases by conducting this selection through two stages: first, one author (DS) examined the list of the most recent meta-analyses focusing on general populations (i.e., non-clinical), including both those examining the effects of physical activity as a treatment for depression, and those examining its role as a preventive factor for incident depression. Factors that were used to select these sets of meta-analyses to focus on, out of a list of 156 available per the systematic PubMed/MEDLINE search, were: having being published within the past 10 years, being published in reputable journals (based on comparative impact factors across the journals where the meta-analyses found through the search were published), number of citations (with consideration of time since publication), inclusion and exclusion criteria (which we restricted to meta-analyses of RCTs when physical activity was examined as a treatment for depression, and to prospective cohort studies when physical activity was examined as preventive factor for incident depression), and methods used by meta-analyses authors to appraise the literature. After DS made an initial selection of relevant meta-analyses to highlight, JT and ES critically reviewed the selection, and provided recommendations (removing some, adding others) based on the quality of the systematic review and meta-analytic processes involved. Despite this comprehensive process, it is still possible that the meta-analyses included do not fully cover the full extent of the evidence in this field, and/or, that our interpretation of the findings does not align with that of others in the field.

5. Scoping review of reviews assessing studies reporting pre- to post-COVID-19 pandemic changes in physical activity levels

Objective
To conduct a review of reviews, also known as an umbrella review, to compile evidence from multiple systematic reviews on the population level changes in physical activity occurring from before the onset of the COVID-19 pandemic (pre) to during the COVID-19 pandemic (post).

Methods

Databases
We conducted a review of reviews by searching the PubMed/MEDLINE and SCOPUS databases, following PRISMA guidelines for scoping reviews (considering review papers as the unit of analysis).

Language
We only searched for systematic reviews (including rapid reviews), with or without meta-analysis, published in English.

Dates
No time or date restrictions were used during the search, but the search criteria, as defined by our search terms, helped ensured that only systematic review articles published within the context and timeline of the COVID-19 pandemic (i.e., as of 2020) were included. The search was run on June 18, 2023.

Search Criteria
We searched for articles including:
- A “review” term in the title.
- A “COVID-19” term in the title.
- A “physical activity” term in the title or abstract.

Supplementary Table 7. Search terms used in review of reviews to assess changes in physical activity during COVID-19.

Review search terms	COVID-19 search terms	Physical Activity search terms
review OR meta-analysis OR “meta analysis”	COVID-19 OR coronavirus OR SARS-CoV-2	“physical activity” OR “physical inactivity” OR “leisure-time activity” OR “active leisure” OR “active transport” OR “active travel” OR exercis*

Eligibility criteria
We conducted an initial scan of titles and abstracts to determine eligibility of each review. The scan was performed by DS (lead author) and two trained Graduate Research Assistants. All discrepancies were resolved by a joint meeting to reach consensus. Eligibility criteria included:
- English language publication
- The review is of quantitative studies
- Narrative reviews and any other paper format (commentaries, letters to the editor, etc.) beyond quantitative systematic reviews were excluded.
- The review is a standard systematic review, with our without meta-analysis, or a rapid review of quantitative studies, or a scoping review of quantitative studies.
- One of the primary aims of the review is to summarize evidence on changes in physical activity levels during the COVID-19 pandemic.
- Reviews focusing exclusively on summarizing changes in other movement behaviours (sedentary time, sleep) were excluded.
- The review focuses on changes in physical activity among the general population, or on clinical or sociodemographic groups of interest, but reviews focused on impacts of the pandemic on elite athletes, athletic performance, training schedules among athletes, etc., where not included. This, since the review is focused on the public health impact of the pandemic on the broader population.

- The review focuses on “naturally occurring” changes in physical activity levels and patterns occurring from before to during/after the COVID-19 pandemic, versus on the effectiveness of physical activity interventions during the pandemic.

Data Abstraction
Data abstracted included:

- Journal name
- Publication date
- Author information
- Whether the review included a meta-analysis
- Population of focus
- Date range of articles searched within the review
- Number of articles identified for data full text abstraction
- Summary of findings (including the overall conclusion of the review, i.e., does the review support that physical activity declined, increased, or stayed the same during the pandemic; or, is it inconclusive?)
- Methodological limitations

Methodological limitations
The large variability in methods used to quantify changes in physical activity across individual studies and for presenting summary findings in systematic reviews, and in the quality of the included studies, yielded a wide range of reported reductions. For example, some studies reported changes in the percentage of the population meeting WHO guidelines, others report changes in daily or weekly minutes of moderate- to vigorous-intensity physical activity, others used MET-Minutes per day or week, and others use single cross-sectional survey items to assess respondent’s perceptions on whether their physical activity levels increased, decreased or stayed the same relative to what they recall was happening before the onset of the pandemic. A large proportion of studies (>40%) relied on cross-sectional surveys. The systematic reviews assessed indicate that these studies tended to report higher effect sizes than those of longitudinal study designs. However, the key finding of significant declines in physical activity during the COVID-19 pandemic remained consistent across study designs. Notably, all studies including objective measures of physical activity (device-based) reported significant declines, strengthening the credibility of the general conclusion that the physical activity of adults and youth declined substantially during the pandemic across the globe. However, the findings of this review of reviews should be contextualised within the limitations of the available reviews and studies included.

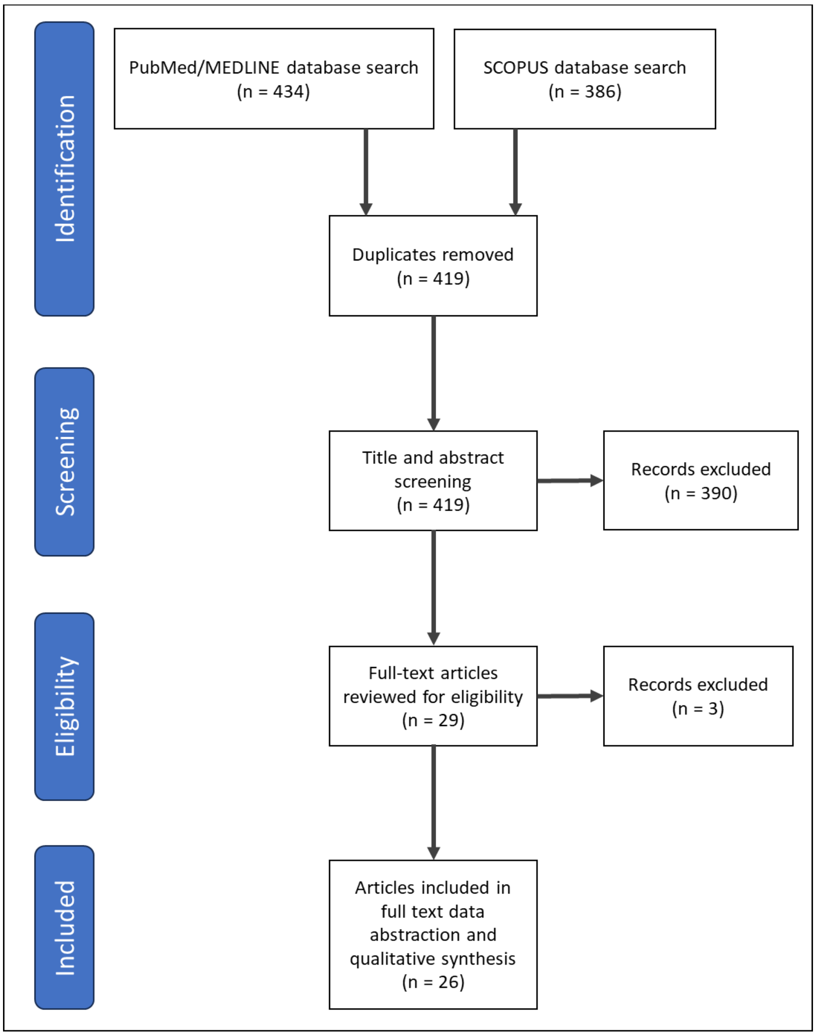
Other limitations of this review and review refer to the search criteria employed. We only reviewed English-language reviews, which may have inserted selection bias, potentially omitting evidence especially from low- and middle-income countries. Likewise, our physical activity search terms were general and did not include more specific types of physical activity (e.g., sports, walking, cycling, dancing). This was a purposeful decision as we aimed to summarize the evidence on general changes in physical activity levels during the pandemic, versus in specific types of physical activity behaviours.

Results

Summary
Findings from the scoping review of systematic reviews summarizing the results of studies assessing changes in physical activity during COVID-19 supports that the pandemic led to reductions in population levels of physical activity (details available in the Supplementary Materials). Among the reviews identified (n=26), Wilke and colleagues meta-analysed data of 320,636 participants of all age groups from 41 countries, and reported a standard mean difference of total physical activity, relative to pre-pandemic levels, of -0·65 (95% CI: -1·10, -0·21).[26] However, given the multiple different approaches used to report changes in physical activity across the studies included in this meta-analysis, it is was not possible to estimate the overall magnitude of change expressed as minutes per day of moderate- to vigorous-intensity physical activity. On the other hand, Neville and colleagues conducted a meta-analysis using pooled longitudinal data of 14,216 children and adolescents, and estimated a 20% (17 minutes

per day) reduction in moderate- to vigorous-intensity physical activity.[27] Limitations of some of these data include sub-optimal study methodology (e.g., asking participants to recall pre-pandemic levels of physical activity versus objectively assessing physical activity in real time before and during the pandemic), and a dearth of studies from LMICs beyond Asia. Notably, those studies that employed device-based physical activity measures in real time before and during the pandemic reported significant declines in physical activity.

Supplementary Figure 2. PRISMA diagram of scoping review of reviews assessing pre- to post- (during) COVID-19 changes in physical activity. Search was performed in June, 2023.



Supplementary Table 8. Summary data abstraction table of systematic scoping review of reviews of pre- to post-COVID-19 pandemic changes in physical activity (n=26).

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Wunsch 2022[28]	PubMed, Web of Science, and Scopus	General population.	Inception to Oct 6, 2021.	57	Yes	32 studies report a significant decline in PA, 5 studies found a significant increase in PA during the Covid-19 pandemic. 14 studies had mixed results. PA decreased in all age groups, independent of gender. Most self-reported and all device-based measurement methods showed a reduction in PA.
Rezende Oliveira 2022[29]	Embase, Pubmed, Cochrane, Web of Science and Scopus	Older adults (60 and over)	Dec 2019 to Oct 2021	25	No	All studies reported significant reductions in PA. 14 cross-sectional and 11 cohort studies.
Viner 2022[30]	PubMed, PsycInfo, Web of Science Social Citation Index, Australian Education Index, British Education Index, Education Resources Information Centre, WHO Global Research Database on COVID-19, MedRxiv, PsyArXiv, Research Square, and COVID-19 Living Evidence	Children and adolescents (aged 0-19 years).	Inception to Sep 1 2020.	7	No	In cross-sectional convenience samples from the US, Scotland, and India, 36% to 47% of children and adolescents reduced their PA, while 24% to 24·4% increased it more physical activity. A Spanish study reported that mean daily physical activity fell 52% (weekly minutes pre: 198·6; post: 95·5). A medium- quality Italian pre-post study of children and adolescents with obesity found a decrease in physical activity of 2·3 hours per week.
Ng 2022[31]	MEDLINE, Embase, SPORT Discus, Cumulative Index to Nursing and Allied Health, PsycINFO, Cochrane, and Physiotherapy Evidence Database	General healthy population, and adults with chronic diseases.	Nov 2019 to May 2021	36	Yes	Moderate evidence from wearable sensors supported a significant reduction in pooled estimates of step count (standardized mean differences [SMD]=2·79, P<.01). Very limited to limited evidence substantiated significant decreases in self-reported PA-related outcomes.

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Stockwell 2021[32]	PubMed, EMBASE, PsycINFO, CINAHL, Social Science Citation Index, Cochrane Central Register of Controlled Trials, SPORT Discus, Scopus.	General population.	Nov 2019 to Oct 2020	66	No	The majority of studies show that PA levels decreased during the COVID-19 lockdown across all reviewed populations, except for eating disorder patients. This includes evidence for declining PA during COVID-19 for healthy adults, children and adolescents, and adults and children with medical conditions.
Do 2022[33]	PubMed, PsycInfo, SPORTDiscus, Web of Science, Academic Search Complete, CINAHL, MEDLINE, and Embase	Youth ages 5-17 years.	Inception to May 10, 2021.	51	No	Most evidence indicated an overall decrease in youth PA levels during the pandemic with differences observed among sub-populations (e.g., age, sex or gender), type, and location. Findings suggest pandemic-related closures hindered PA participation due to a high reliance on school- and sport-based PA. Results also indicated an increase in outdoor and unstructured youth PA during the pandemic.
Perez-Gisbert 2021[34]	CINAHL, Medline (via Pubmed), Scopus, andWeb of Science	Adults with NCDs	Inception to January 14 2021	5	Yes	Of the 5 studies, only three studies were included in the meta-analysis. Two articles used accelerometers to objectively compare PA levels before and during the pandemic. Three studies made this comparison using an online survey. All articles showed a decrease in PA levels during the COVID-19 pandemic. The meta-analysis showed a significant reduction in PA levels during pandemic. PA levels during the COVID-19 pandemic have been reduced compared to previous levels of PA in patients with NCDs.
Christensen 2022[35]	PubMed, MEDLINE, CINAHL, SPORTDiscus, Academic Search Complete, APA PsycInfo, and APA PsycArticles	Adults (18 years or more)	Dec 2019 to Jan 2021	66	No	44 studies reported changes in physical activity, with 25 doing so via a "categories of change" approach (increase, same, decrease). Of these, 13 reported decreases, 10 no change, and only 2 reported increases. Ten studies reported change based on a continuous variable of time spent of MET-time in PA. Of these, all but one reported decreases. Three studies used objective measures (devices), and all reported decreases. Five studies reported changes in MVPA, of which 4 reported decreases. Seven studies reported change in walking, with six reporting decreases.
Park 2022[36]	Pubmed and Google Scholar	General population	Jan 1 2019 to Nov 1 2020	61	No	The results showed that COVID-19 was linked with significant decreases in mobility, walking, and physical activity. A few studies also reported contradicting results including increased uses of parks/trails and increased recreational activity among certain groups of population. The majority (78·3%) were conducted in Asian (mostly China) and European countries, with only four (6·7%) being US studies.

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Abasiyanik 2022[37]	PubMed, CINAHL (EBSCO host), Web of Science (WOS), SCOPUS, and the Cochrane Library.	People with neurological diseases	Inception to Feb 4 2021	14	No	Thirteen studies reported a decreased physical activity level (out of 14). Physical activity reduction was associated with worse disease symptoms, depression, perceived health, and mental and physical components of quality of life.
de Boer 2021[38]	Pubmed, CINAHL, PsycINFO, Embase	Adults with Physical Disabilities and/or NCDs	Dec 1 2019 to Sep 30, 2020	29	No	Twenty-five studies (96%) reported no difference or a decrease in PA, with 59% of the studies reporting a decrease in PA levels.
Zaccagni 2021[39]	PubMed and Scopus	Italian citizens (adolescents to older adults)	Inception to Dec 31 2020.	23	No	Most studies highlighted a significant reduction in the amount of performed physical activity compared to before lockdown, in both the general population and in individuals with chronic conditions. Two studies reported an increase in PA mainly in highly active people and PA beginners.
Wilke 2022[26]	PubMed, Web of Science and Google Scholar	General population	Inception to Sep 2021	174	Yes	The study found a moderate decrease in total PA, a smaller decrease in magnitude in walking, light-intensity, moderate-intensity, and vigorous-intensity PA. While PA decreases affected all continents, no reduction was found for Australia when compared to the reference (Europe).
Neville 2022[27]	PubMed, PsycInfo, SPORTDiscus,Web of Science, Scopus, CINAHL, and MEDLINE	Children and adolescents (age ≤18 years)	Jan 1, 2020, to Jan 1, 2022	126	Yes	Child and adolescent engagement in PA decreased by 20% during the pandemic. Moderation analysis showed that the size of the change in PA before and during the pandemic differed between intensity levels and was larger for higher intensity activities, MVPA had a decrease of 28%or 17 min reduction in daily MVPA.
Pang 2023[40]	CINAHLComplete,Cochrane Library, EMBASE, Medline, PubMed, and PsycINFO	Preschoolers (age 0–5 years), children (age 6–11 years), and adolescents (age 12–18 years) (worldwide, participants of final studies were from 23 countries)	Inception to Mar 16, 2022	44	Yes	Nine articles found a significant decrease in PA time during the COVID-19 pandemic (23·2 minutes per day). PA time significantly decreased for preschoolers (29·6 min/day), for children (18·8 min/day), and for adolescents (19·4 min/day).

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Khan 2022[41]	PubMed Embase, Scopus, PsycInfo, Cochrane, CINAHL and Web of Science; selected sources of grey literature and the preprint archive medRxiv	General population	Inception to Feb 2021	41	No	PA decreased in most studies to between 18 and 84%. Four studies reported an increase or the same levels of PA when compared to before the pandemic.
Buizza 2022[42]	PubMed, EBSCO, SCOPUS and Web of Science	University students	Inception to May 2021	17	No	Of the 17 studies only one reported a decrease in physical activity, and another study reported physical activity as a possible protective factor of college student mental health during the pandemic.
Chaabna 2022[43]	PubMed, Embase, WHOGlobal literature on coronavirus disease, and reference lists	General and patient population of all age groups	Jan 2020 to Apr 2021	63	Yes	Sixty-three primary studies revealed a significant decrease in PA levels in children and adults. During the period of COVID-19 MR, children had significantly lower odds to meet the WHO PA recommendation than adults. Patient populations were less active than the general population, and their PA levels decreased during the pandemic. A significant difference of PA prevalence in adults was demonstrated between countries. More males appeared to be active than females before and during the pandemic. Sub-group meta-analysis and meta-regression identified the following factors as significant in explaining some of the variability between studies among adults: country, instruments used to measure PA levels, sample size, and sampling method. In addition to the instruments used to measure PA levels, study setting, and design were identified as significant in explaining some of the variability between studies among children.
Kharel 2022[44]	PubMed/ MEDLINE, Web of Science, Cumulative Index of Nursing and Allied Health Literature (CINAHL), PsycINFO	Children and adolescents (aged 19 years and below)	Mar 11, 2020, to Jan 27, 2021	71	No	Twenty-five studies (eight cohort and 16 cross-sectional and one qualitative) observed a decline in PA, eight (two cohort, five cross-sectional and one qualitative) observed no change and one (cohort) reported an increase in physical activity. Reductions in PA levels were observed among children and adolescents in Chile, Singapore, the UK, Croatia, Australia (New South Wales), Canada, Poland, the USA, China, France, Portugal, Italy, Spain, Brazil, and Turkey. In some countries, children and adolescents could maintain (Italy, China, Australia (Western Australia) and Poland) or even increase (Germany) their PA levels despite the pandemic restrictions.

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Lopez-Valenciano 2022[45]	Cochrane Library, PubMed, SPORTDiscus, and Web of Science	University students	Inception to Oct 2020	10	No	Nine out of the ten studies included in the systematic review showed significant decreases in PA levels during lockdown, both in questionnaires as accelerometers. One study showed significant increases in PA levels among university students during lockdown. Five studies showed a reduction of light/mild PA (walking), three studies found a decrease in moderate PA levels, four studies reported a decrease in MVPA, and seven studies reported a decrease in vigorous PA compared to pre-lockdown. Two studies found higher decreases in PA in males.
Mekanna 2023[46]	Web of Science, PubMed, and Scopus	General population	Mar 11, 2020, to Jan 27, 2021	22	No	Eleven studies reported decreased physical activity during lockdowns compared with before it, followed by an increased physical activity post-lockdown compared with during lockdowns. One study reported that vigorous activity was not affected during lockdowns, and two others noted it increased during lockdowns.
Chew 2021[47]	CINAHL and PubMed	General population	All studies published through May 14 and July 5, 2021, were included.	19	No	Fourteen studies reported changes in physical activity levels. Four studies reported an increase in PA, seven reported a decrease in PA levels, mean duration or METs.
Larson Elisabeth 2021[48]	PubMed and EBSCO LISTA	Older adults (50+years)	All studies published between January 2020 – March 2021.	27	No	Sixteen studies reported a decrease in physical activity, one study from northern Cypriot females reported increased PA levels, and a study from older UK adults (76 to 97 years) reported mixed results.
Rivera 2021[49]	PubMed, MEDLINE, Embase, SCOPUS, and APA PsycInfo	University students	All studies published through January 05, 2021, were included.	7	No	Studies on undergraduate students reported a decrease in light-intensity PA, one study found NS change and one a significant decrease in moderate PA, and three studies reported on vigorous PA with non-significant changes in levels on two studies and one study reporting a significant decrease. Mixed results were found for total MVPA change. Neither of the two studies reporting physical activity outcomes in graduate students found statistically significant changes in PA levels of any intensity.
Mehraeen 2023[50]	PubMed, Scopus, and Cochrane	General population (and were from 28 countries).	All studies published from the start of the pandemic through May 03, 2021, were included.	57	No	Fifty studies indicated a substantial decline in PA levels during the COVID-19 pandemic, one study reported no change and size studies reported significant increases in PA levels (studies from Spain, Germany, Saudi Arabia, South Korea, and Turkey). The studies on children showed that the PA level in school-aged children either increased or remained unchanged at home.

Author & Year	Databases searched	Population	Dates included	n of articles abstracted	Meta analysis	Main Findings
Paterson 2021[51]	Medline, SportDiscus, Medline (Ovid), and Embase (Ovid)	Children and adolescents 5-17 years of age	All studies published between March 11, 2020, and January 27, 2021, were included	150	No	Forty-four studies compared pre-pandemic and during pandemic behaviours and concluded that PA frequency and duration decreased during the pandemic in children and youth, this was demonstrated repeatedly in both longitudinal and cross-sectional designs. This result was echoed by those of other studies using similar constructs, including exercise time, energy expenditure, and MVPA. The exception was one German longitudinal study that reported an increase in the proportion of children and youth meeting guidelines. From the three studies that used device-based PA measures, only two studies included a comparison of PA levels, results were consistent with the studies using self- and proxy-reported PA (i.e., all showed decreases).

6. Scoping review of original research studies explicitly examining the possible impacts of the COVID-19 pandemic on sociodemographic physical activity inequalities

Objective
To conduct a scoping review of original research papers that explicitly examine the possible impacts of the COVID-19 pandemic on sociodemographic (socioeconomic, and racial/ethnic) physical activity inequalities.

Methods
Databases
We conducted a scoping review by searching PubMed/MEDLINE and SCOPUS following PRISMA guidelines for systematic scoping reviews.

Language
We only searched for English-language articles.

Dates
No time or date restrictions were used during the search, but the search criteria, as defined by our search terms, helped ensured that only systematic review articles published within the context and timeline of the COVID-19 pandemic (i.e., as of 2020) were included. The search was run on September 20, 2023.

Search Criteria
We searched for articles including:
- A "physical activity" term in the title or abstract.
- An "inequality" term in the title or abstract.
- A "COVID-19" term in the title.

Supplementary Table 9. Search terms used in review of reviews to assess changes in physical activity during COVID-19.

Physical Activity search terms	Inequality terms	COVID-19 search terms
"physical activity" OR "physical inactivity" OR "leisure-time activity" OR "active leisure" OR "active transport" OR "active travel" OR exercis*	inequalit* OR disparit* OR inequit* OR "socioeconomic differenc*" OR "sociodemographic differenc*"	COVID-19 OR coronavirus OR SARS-CoV-2

Eligibility criteria
We conducted an initial scan of the search results, by examining titles and abstracts, to determine eligibility of the article for full data abstraction. The scan was performed by DS (lead author). Eligibility criteria included:
- English language publication
- The article presents original research.
- Commentaries, letters to the editor, personal viewpoints, case studies, and systematic and narrative reviews were excluded.
- The article uses quantitative methodology to assess sociodemographic physical activity inequalities as a result of the COVID-19 pandemic.
    - Articles using mixed methods, reporting both on quantitative and qualitative findings were included, but only quantitative results were abstracted.
- An explicit and primary aim of the article is to assess differences, or to explore inequalities, in changes in physical activity levels during the pandemic, by sociodemographic factors (with focus on the socioeconomic and race/ethnicity dimensions of inequality).
- Papers focused on gender inequalities, age inequalities, or other types of inequalities and not including an assessment of socioeconomic or racial/ethnic inequalities were not included.
- Articles focusing exclusively on summarizing changes in other movement behaviours (sedentary time, sleep), but not including measures of physical activity (which can

include measures of walking, cycling, active play, and traditional quantifications of MVPA); were excluded.
- Articles assessing effects of interventions or programs intended to promote physical activity during the pandemic on physical activity were excluded, as our focus was to assess the "naturally occurring" changes in PA and their potentially differential impacts across demographic groups.
- Articles not assessing pre- to post- (during) pandemic changes were excluded, including those with multiple time-points during the pandemic, but with no pre-pandemic physical activity assessment.

Data Abstraction
Data abstracted for this scoping review included:
- Journal name
- Publication date
- Author information
- Whether the results support evidence of differential impacts of the COVID-19 pandemic by socioeconomic or racial/ethnic characteristics.
- Whether the results support evidence of widening inequalities in possible connection to the COVID-19 pandemic (i.e., the article assessed pre- and post- inequalities and whether the degree of inequality increased/decreased during the pandemic).
- Text description of the key findings with regards to physical activity inequalities in connection to COVID-19.
- Study design
- Physical activity assessment measure(s) used
- Population of focus.

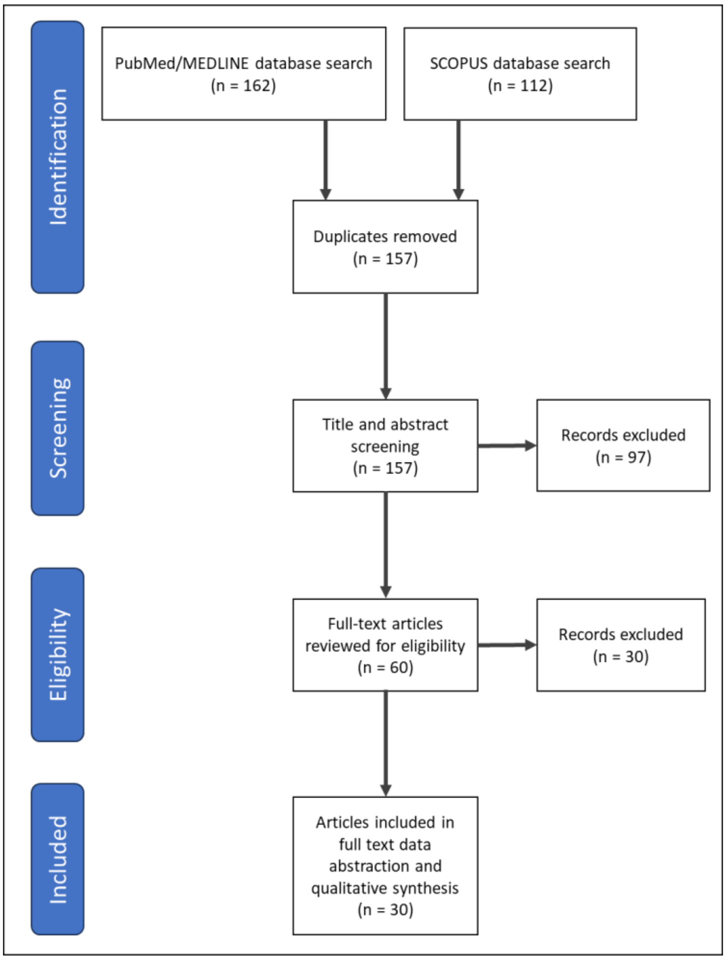
Methodological limitations
A large portion of studies used small, non-probabilistic samples, and a cross-sectional design whereby pre-pandemic levels of physical activity were based on participant recall at the same point in time when current (during- or post-pandemic levels) were being reported. Further, the ways in which inequalities were assessed were highly variable, ranging from stratification of findings with respect to changes in physical activity by sociodemographic characteristics of interests with relatively simple statistical analyses (ANOVA, Chi Square tests), to multivariable regression methods assessing interaction effects, to the calculation of pre-post differences in formal measures of inequality (e.g., slope index).
Because this was a scoping review, a detailed appraisal of the quality of each study was not conducted, but studies were classified by study design, and information on whether representative population samples (vs. convenience sampling approaches) were used was abstracted. We also abstracted data on the measures (and whether they are validated) used to assess pre- and post-levels of physical activity. As with the review of reviews, this scoping review was restricted to English-language publications, and as such, is prone to selection bias. Further, the search terms used to define physical activity are general, and do not include terms specific to the occupational and home-based domains of physical activity, nor to specific types of activities (e.g., specific sports, walking, cycling, dancing, etc.). As with the review of reviews, this was a purposeful decision, as we were interested in identifying studies that assessed general changes in population levels of physical activity and their differences by socioeconomic characteristics, to determine if there is available evidence supporting the notion of exacerbation of pre-pandemic physical activity inequalities.

Results

Summary
A likely, yet difficult to quantify consequence of the COVID-19 emergency was the widening of pre-existing health inequities due to differential opportunities for physical activity among people of varying circumstances and backgrounds during the pandemic.[52–54] A scoping review of studies assessing changes in physical activity inequalities before versus during the COVID-19 emergency was conducted by our team (details available in the Supplementary Materials). We identified 30 published studies that examined differences in physical activity changes during COVID-19 by socioeconomic status (income, education, wealth) and/or race/ethnicity. A large portion of studies (n=25, 83·3%) reported steeper reductions in physical activity among the most

disadvantaged groups (low income, low education, racial/ethnic minorities), relative to the most privileged groups. However, most studies relied on relatively small, convenience-based samples, and/or on single time-point assessments (e.g., asking participants to recall their pre-pandemic physical activity levels and compare them to their recall of during/post-pandemic levels). Fewer than half of the studies (n=12, 40%) utilized more appropriate study designs with representative, population-based samples, including serial cross-sectional studies and large prospective cohorts. A smaller set of studies (n=7, 23·3%) calculated pre- to post-pandemic differences in absolute (e.g., slope index) and/or in relative (e.g., Gini coefficient) measures of inequality. Importantly, all studies judged be of higher quality reported evidence suggestive of widening physical activity inequalities. It should be underscored, however, that with the current evidence, it is not possible to quantify or distinguish the contributions of the more direct consequences of COVID-19 (e.g., experiencing long COVID-19, having to take care of ill relatives, or losing a family member due to COVID-19), versus the more indirect consequences of the pandemic (e.g., loss of employment or limited access to public open spaces due to pandemic response policies), on the widening of physical activity inequalities.

Supplementary Figure 3. PRISMA diagram of scoping review of review of studies assessing the impact of the impact of the COVID-19 pandemic on physical activity inequalities.



Supplementary Table 10. Summary data abstraction table of scoping review of articles explicitly assessing the potential impact of the COVID-19 pandemic on socioeconomic and racial/ethnic physical activity inequalities (n=30).

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Parker 2023[55]	Cross-sectional, online survey	Young adults, 18-24y, US based	Single item on perceived degree of PA change (Likert scale)	A third of the participants (33%) reported becoming less active and more than a third (39%) became more active. There were no significant social group differences in reported activity levels, i.e., no evidence of physical activity inequalities.
Titus-Lay 2023[56]	Cross section, convenience sample, recruited at COVID vaccine clinics	18 years +, California based, attended a COVID vaccine clinic	Single item on perceived degree of PA change (Likert scale)	Black and Latino/Hispanic respondents were significantly more likely to have reported decreasing their PA during the pandemic relative to before; and likewise, significantly less likely to have reported increases in PA during the pandemic, than their White counterparts.
Duncan 2023[57]	COMPASS collects data annually (2012–2027) from a rolling cohort of students attending a convenience sample of secondary schools across Canada	School age children/adolescents, grades 7 to 12 (exact ages not reported)	Self-report, pre and post. MVPA assessment tool for national surveillance of youth (validated for Canada)	Using multivariable regression modelling and testing for interactions, this study found evidence of lesser declines/higher adherence to pre-pandemic PA among those of higher socio-economic status. Also, evidence of white children having lesser PA declines during the pandemic than Asian participants. Sample size of 8274 participants with pre and post data.
Maximova 2023[58]	Serial cross-sectional, pre and post lockdown measures; among 11 rural schools in Canada.	Elementary students of rural elementary schools in Canada, ages 9-12 years	PAQ-C (validated instrument)	Inequalities in PA were assessed with a Gini coefficient. The study reports evidence of significantly widening PA inequalities due to COVID-19, with a GINI coefficient (based on wealth inequality). The GINI coefficient of inequality significantly increased based on pre and post measures, indicating widening PA inequalities (Gini-coefficient change: 0·016 [0·001,0·030)

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Gu 2023[59]	Cross sectional study, online survey in Texas, for parents.	1394 children and adolescents aged 3-17 years of age, state of Texas, US.	Godin-Shephard Leisure-Time Physical Activity Scale (LTPA) was used to capture the intensity level of PA including light PA [LPA], moderate PA [MPA], and vigorous VPA [VPA] before and during COVID-19. Youth play behaviours during COVID-19 were measured with a 7-item scale including outdoor PA (in yard, neighbourhood, and community) and indoor PA (child-led PA, parent-led PA, and online PA). Based on parental recall.	Low-SES and Hispanic minority youth reported significantly less safety to walking or playing in their neighbourhoods than their middle-/high-SES non-Hispanic peers ($p < .001$). Regardless of ethnicity, the magnitude of the reduction of MVPA was significantly higher among low-SES groups than that of the high- and middle-SES groups ($p < .001$).
Stratton 2023[60]	Cross sectional, online, convenience survey	1882 Adult women from Mexico (18+ years)	Physical activity behaviours before and during the pandemic were assessed by asking participants how many days per week they engage in 30 min or more of PA. Physical activity was classified into three categories of performance: (1) low (< 2 days/week); (2) moderate (2–4 days/week); and (3) high (≥ 5 days/week).	Among the respondents, 53·3% declared that their PA was reduced during the pandemic, 26·6% reported similar PA behaviour, and 20·1% declared that their PA had increased during the pandemic. Lower PA behaviour during the pandemic was associated with lower education levels.
Jääskeläinen 2023[61]	Longitudinal cohort of national representative sample of Finnish adults from the FinHEalth 2017 study, with pre-pandemic data from 2017 and during pandemic data in 2020.	Finnish adults aged 25-69 years.	Self-report, using questions about time spent in leisure time PA, moderate intensity exercise, and vigorous intensity exercise.	Those of low SES background before the pandemic were prone to unfavourable lifestyle changes during follow up (Including PA changes). Specifically, reporting having insufficient money (pre-pandemic) was associated with higher risk of decreasing overall time spent in leisure time PA.

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Katewongsa 2023[62]	Serial cross-sectional using representative data from Thailand's Surveillance on Physical activity dataset at two time points (2020 which collects 2019 data, and 2021 which collects 2019 data). Online based but nationally representative using data from the National Statistical Office.	Adults 18+ (both time points had sample sizes larger than 6500 participants). Thailand.	Self-report, based on recall of general activity level from previous year.	This study examined declines in PA during the pandemic, and recovery rate (if and how fast the population returns to pre-pandemic PA levels). It found full recovery has not been achieved by most, and that recovery is slower among some groups, including some that represent low SES groups (students, the unemployed).
Kyan 2023[63]	Repeated cross sectional study using representative data of children and youth in Japan	700+ participants per wave, 12-18 years of age, Japan	Self-reported instrument for leisure time PA	Calculated slope index of inequality for percent of participants spending at least 60 minutes in MVPA per day before and during the pandemic. Compliance with MVPA significantly declined from 2019 to 2021. The slope index of inequality and relatively index of inequality significantly increased in MVPA by SES status, such that the gap between the poorest and richest households became more pronounced.
Quirk 2023[64]	Cohort study of participants enrolled in the UK parkrun program, with two assessments of PA. Not representative sample.	438 adults from the UK enrolled in the Parkrun program, mean age 47.	Milton et al single item questionnaire assessing weekly frequency of participation in PA. Change was calculated for during vs. pre-pandemic days per week.	The change in physical activity participation frequency from before (Jan/Feb 2020) to during the COVID-19 pandemic (Sep 2020) was significantly larger for participants living in the most deprived areas compared to those in the least deprived groups; that is, the activity level of the high deprivation group fell by 0·52 days per week while the low deprivation group fell by 0·14 days per week (effect size 0·19, $p < 0·05$)
Silva 2023[65]	Data from 4 nationally representative cohorts in England assessing PA levels before and during the pandemic took place. Individual level data was geographically linked to neighbourhoods of residence to assess area deprivation.	Adults (18+) in England. 18,000+ participants.	Self-reported weekly participation in PA	Evidence from nationally representative cohort studies in England shows that relative to prior to the pandemic (2019), during the onset of the pandemic (2020) PA increases were observed in the population. However, increases were significantly lower among residents of socioeconomically deprived neighbourhoods as compared to residents of well off areas.

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Michael 2023[66]	Serial cross-sectional data from the Youth Risk Behavior Survey in the US, from 2019 to 2021 waves; nationally representative data	nationally representative sample of U.S. public and private school students in grades 9–12 (adolescents)	Self-reported instrument assessing participation in PE, sport, daily leisure PA	This study shows evidence of racial disparities. During 2019–2021, decreases occurred overall for three of the five physical activity behaviours examined (Table 5). The percentage of students who had exercised to strengthen or tone their muscles on ≥3 days/week decreased overall and among female, Black, NH/OPI, and multiracial students. The percentage of students who had attended physical education classes on all 5 days decreased overall and among male, Asian, Hispanic, and NH/OPI students. The percentage of students who had played on ≥1 sports team decreased overall and among female, male, Black, Hispanic, White, and multiracial students. In addition, although the percentage of students who had met the aerobic and muscle-strengthening guidelines did not change overall, the percentage decreased among NH/OPI students.
Brattlöf 2023[67]	Serial Cross sectional study using data from 2018 and 2021.	Swedish samples aged 16 to 84	Self-reported time spent in leisure time PA	Even though PA levels in Sweden increased during the pandemic, so did socioeconomic inequalities in PA. Using a slope index analysis and absolute risk difference calculation, this study concluded that the PA gap between high SES and low SES, and between Swedish-born vs. foreign-born population became wider.
Weihrauch-Blüher 2023[68]	Cross sectional, non-representative online survey of parents of children ages 3-17 in Germany	German children aged 3-17, based on parental report	Self-reported levels of PA before and during PA (recall based)	General declines in PA and fitness were reported, with physical fitness declines in children from low-income families being almost twice as often affected as children from high-income families (43% vs. 25%).
Telias 2022[69]	Cross-sectional study, 505 residents of northern California completed a web-based survey from August to November of 2020.	Adults residing in Northern California (18 years or more)	Self-reported perceived change in PA	49·5 % indicating a reduction in physical activity, with higher reductions reported by Hispanics vs. Whites.
Jáuregui 2022[70]	Cross sectional, non-representative online survey of parents of preschool children from Mexico, Chile, or Latino children in the US	Respondents were caregivers of preschool children in Mexico, Chile, or US (Latinos only)	Self-reported levels of PA before and during PA (recall based)	This study found evidence of declines in PA among children from Mexico, Chile and Latino children in the US. Steeper declines were observed among children living in smaller residential dwellings (expected direction), and among children with highly educated parents (counter-intuitive finding).

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Vazquez 2022[71]	Cross-sectional, non-representative sample of Hispanic parents in Texas	Hispanic parents from Texas, US	Parental reported perceived change in PA (stayed the same, improved, worsened) by children.	No differences in "worsening exercise behaviours" were reported by SES in this cross-sectional survey of a convenience sample of Hispanic parents in Texas, US.
Braithwaite 2022[72]	Cohort study in the UK with at least 2 measurements including pre-pandemic and during pandemic measures.	3231 adults of the Fenland, UK cohort study.	Recent physical activity questionnaire (4-week recall) - validated instrument.	Decreases in physical activity energy expenditure were most pronounced in the most deprived group compared with the least deprived group. Participants born between 1950 and 1975 were originally recruited from general practice registers, a population-based sampling frame across Cambridgeshire, United Kingdom.
Towne 2022[73]	Online, nonprobabilistic sample, single time point assessment (cross sectional), based on pre-pandemic PA recall	Adults 18+ from Texas.	Self-reported MVPA by location (within home neighbourhood or elsewhere).	Statewide online survey in Texas, US assessing adult's self-reported minutes of MVPA comparing a recalled "typical week" prior to the pandemic to a week during the pandemic took place. Negative binomial regression models examined changes in self-reported MVPA by location of PA and sociodemographics. There was evidence of significantly steeper reductions in MVPA among low-income individuals, and those belonging to racial/ethnic minorities (non-white).
Sparks 2022[74]	Online, nonprobabilistic sample, single time point assessment (cross sectional), based on pre-pandemic PA recall	US-based respondents of global online survey. Adults (18 years or more).	Self-reported change in PA	Global (worldwide) online survey assessing changes in health behaviours, including PA, during the pandemic, with 4542 US respondents, which the study focuses on. Changes in PA were assessed by recall (cross-sectional study). While PA declined for the full sample, no significant differences were found by race/ethnicity (no evidence of larger impact of the pandemic on PA by race/ethnicity)
Elliott 2022[75]	Prospective cohort, nonprobabilistic sample	3660 older adults (65 years or more) from the UK.	Self-reported PA using GPAQ	Prospective cohort study of 3660 older adults in the UK (nonprobabilistic sample). Declines in PA were observed across all groups, regardless of neighbourhood deprivation status (SES variable assessed). No evidence of widening PA disparities.
Hu 2022[76]	Nonprobabilistic, convenience sample. PA assessed in single time point, based on recall.	129 caregivers of children ages 2-17 and 34 adolescents ages 13-17 with overweight/obesity, from the US.	Self-reported MVPA for pre vs. during pandemic levels.	Small convenience sample of caregivers of 2–17-year-olds and of adolescents with overweight (13–17-year-old). Cross sectional study based on recall or pre-pandemic PA. Steeper PA declines were associated with household food insecurity (SES measure)

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Widyastari 2022[77]	Serial cross-sectional, pre, during and post COVID, nationally representative samples.	Nationally representative samples of adults 18-64 from Thailand. (n per sample =6000+)	GPAQ	Serial cross-sectional study (three time points) assessing pre-, during- and post-pandemic PA changes, and examining if PA inequalities widened during the pandemic. Nationally representative samples, of over 6000 individuals per round. Constructed an inequality index including the proportion of the population with sufficient MVPA at each time point, cumulative MVPA minutes, and Gini coefficient of socioeconomic inequality. Findings show that socioeconomic PA inequalities widened during the pandemic as demonstrated by relative difference of the Gini coefficient, driven specifically by loss of income among some groups, and low access to PA facilities among low-SES groups.
Lee 2022[78]	Serial cross-sectional study with 5-time points. Representative samples of 7 metropolitan areas of South Korea.	Korean adults from 7 urban areas, aged 19-65 years. Large sample with sampling weights.	PAQ-short form (validated)	This study investigated the five-year (2016−2020) trend in physical activity adherence rate (PAR)—before and after the onset of the COVID-19 pandemic—and its association with socioeconomic status and community environment among Korean adults. Data were analysed from the Korea Community Health Survey 2016−2020 concerning adults (19−65 years old) living in seven metropolitan municipalities of South Korea. Representative samples of these urban areas. The study assessed PA trend prior to the onset of the pandemic, where an increase in PA between 2016 and 2019 was apparent. There was a steep decline in PA during the pandemic, which differentially impacted (was steeper) those with lower educational attainment, for which recovery of pre-pandemic PA levels is taking longer.
Bekelman 2022[79]	Prospective cohorts, nonprobabilistic samples	347 children ages 4-12 and their caregivers from 4 US cities	Parental reported PA at each time point.	Study combining 4 cohorts of children ages 4-12 participating in the Environmental Influences on Child Health Outcomes Program. Sample is relatively small (n=347) and non-representative. Pre and post pandemic PA was assessed via questionnaire at each time point. Upper-middle household income was associated with PA increases during the pandemic.
Beydoun 2022[80]	Prospective cohort	Mid- to older adults in the US (50 years of age plus)	Self-reported frequency of moderate and vigorous exercise (never, 1–4 times per month, or >1 times per week), using the Activities of Daily Living (ADL) questionnaire.	This was a prospective cohort of retirees ages 50+ in the US. Sample is not representative. Assessments of PA recurrently between 2006 and 2020 (immediate pre-pandemic data was of 2018). While the study found evidence of reduction in PA among participants that used to do it a few times per month (but not weekly) before the pandemic, there was no evidence of inequalities in changes of PA from pre to post pandemic by wealth, education, race, and ethnicity.

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Barr-Anderson 2021[81]	Population-based longitudinal study	Young adults (20+) who attended secondary school in Minneapolis-St. Paul, Minnesota, USA when initially recruited in 2009-2010 as part of the EAT 2010-2018 (Eating and Activity over Time) study. Sample 218.	Hours of past-week strenuous, moderate, and light PA were assessed in the EAT 2018 and C-EAT surveys using items modified from the Godin-Shephard Leisure-Time Exercise Questionnaire	Compared to white participants, Black or African American participants and participants of mixed or other ethnic/racial categories reported lower levels of MVPA and total PA during the pandemic stay-at-home order, while participants identifying as Asian American reported higher levels of recreational screen time during COVID-19. Compared to participants of high SES, participants of low SES reported lower levels of MVPA and total PA during the pandemic stay-at-home order.
Bann 2021[82]	5 different prospective population-based cohorts. May 2020 (COVID-19 sample) used an online questionnaire while previous follow ups were not collected online.	Adults 19+ from across the UK. Cohort-specific sample sizes: 1946c: 1,258; 1958c: 5,178, 1970c: 4,223; 1990c: 1,907; 2001c: 2,645.	Single item assessment for exercise (number of days per week (i.e., from 0 to 7) the participants exercised for 30 min or more at moderate-vigorous intensity—"working hard enough to raise your heart rate and break into a sweat")	Lower education was also associated with lower exercise participation, lower childhood social class was more strongly related to lower exercise participation during lockdown. Ethnic minorities had lower exercise levels during but not before lockdown— pooled per cent risk difference during (ethnic minority vs white): 9·0 (1·8, 16·3; I2=0%
James 2021[83]	Longitudinal retrospective cohort using online self-report data from children with free school meal status as a proxy for deprivation.	Children ages 8 to 11 years from Wales, UK that have been completing the HAPPEN (Health and Attainment of Pupils in a Primary Education Network) survey	Physical activity responses were coded as 1 if participants responded with being active for 7 days and 0 if less.	FSM (Free School Meal) status was used as a proxy for deprivation and was obtained via the Secure Anonymised Information Linkage (SAIL) Databank. During school closures, there was a significant improvement in physical activity (see table 2) (4·5% increase in number achieving 60 min of physical activity a day, 95% CI: 0·95% to 8·14%). There were no significant differences in these variables between 2018 and 2019 suggesting that these findings are associated with lockdown restrictions and school closures as opposed to time trends. During school closures, there was a significant difference of reported daily physical activity between those on FSM and those not on FSM (13·03% difference, 95% CI: 3·3% to 21·66%. Compared with non-FSM children, a lower proportion of FSM-eligible children reported to engage in at least 60 min of daily physical activity during school closures (non-FSM: 28·12%; FSM: 15·09%).

First author and year of publication	Study design	Population	Physical activity assessment measure	Main Results
Weaver 2021[84]	Cross-sectional, online survey using Prolific Academic, a method of online participant recruitment that cross-stratifies on age, ethnicity, and sex, to obtain a representative US sample using Census Bureau population group estimates.	Population	Physical activity behaviours before and during the pandemic were assessed by using the IPAQ-SF	Being Black was significantly associated with a decrease in total METs expenditure; using non-Black participants as the comparison group in a multivariable regression model.

7. Lessons from the COVID-19 pandemic for integrating physical activity in public health emergency preparedness and response

The beneficial effects of physical activity for immunity, COVID-19 outcomes, depression, and cancer, in addition to its well-known role for obesity and associated cardiometabolic disease prevention and control (risk factors for severe COVID-19), supports that physical activity could have played an important role in buffering some of the negative consequences of COVID-19. However, significant population physical activity declines were observed during the pandemic worldwide across all population groups[26,27] (see scoping review of changes in physical activity during COVID-19 in the Online Supplement).

Given the threat of a new, potentially fatal, highly transmissible virus, with no effective treatments or vaccines available at the onset of the pandemic, multiple governments ordered the temporary closure of places for leisure physical activity (e.g., health clubs, dance studios, schools).[85–87] Many jurisdictions also temporarily closed outdoor public environments, like parks, playgrounds, sports fields, and trails. Some cities suspended or reduced mass public transit service, with city buses and trains identified as high-risk settings for SARS-CoV-2 transmission.[88–91] Meanwhile, few governments actively promoted physical activity during the pandemic.[87] It is important to recognise that lack of evidence on how to safely use physical activity settings without exacerbating SARS-CoV-2 transmission may have deterred national and local governments, who did not have the benefit of hindsight, from widely promoting physical activity prior to vaccine availability.

The COVID-19 emergency also underscored the importance of physical activity for health equity, crisis resilience, and social justice during major crises. For many across the world, the only opportunities for active leisure are at publicly accessible places like parks, trails and free-access recreation centres (health equity).[87,92–94] It is plausible that the closure of these locations may have contributed to widening pre-pandemic physical activity inequalities (see scoping review of studies assessing the impact of the COVID-19 pandemic on physical activity inequalities in the Online Supplement). These settings are also known facilitators of social interaction and nature contact, two contributing factors, along with physical activity, to good mental health.[94,95] Some studies reported that the negative mental health impacts of the COVID-19 emergency were less frequent among those who remained physically active during the public health emergency period (crisis resilience), [96–98] although reverse causality cannot be discarded. Additionally, the higher risk of becoming ill with COVID-19 among public transit users exemplified some of the social injustices associated with necessity-based physical activity occurring under suboptimal safety conditions (as public transit use inherently requires some physical activity for walking to and from transit stations). For many people, public transit is the main mode of travel and the only means for accessing key destinations, including jobs, hospitals, and clinics.[92]

8. Epidemiological evidence of the effect of physical activity on cancer incidence, survival, and additional survivorship outcomes

Objective
To identify the most relevant epidemiological evidence of the associations between physical activity and cancer outcomes.

Methods
A narrative review of the literature of the epidemiological evidence for the associations between physical activity and cancer incidence and survival (mortality) was conducted. This process involved two main stages: (1) searching and identifying high-quality reviews and meta-analyses; and (2) supplementing with information from high-quality narrative or umbrella reviews, if available, and from high-quality original research papers published since the last high-quality review.

Databases
DS searched PubMed/MEDLINE for English language, peer-reviewed, systematic reviews and meta-analyses that examined the relationship of physical activity and cancer prevention and control.

Language
We only searched for systematic reviews published in English.

Dates
The review was limited to systematic reviews and meta-analysis published since 2015. The search was last updated in October, 2025.

Search Methodology
Outcomes of interest included cancer incidence, cancer survival (including both all-cause mortality among people diagnosed with cancer, and cancer-specific mortality), and additional survivorship-related outcomes (e.g., mental health, quality of life, etc. among people living with cancer).

Given the large number of systematic review and meta-analyses on the associations between physical activity and cancer and cancer-related outcomes, our review focused only on reviews about all cancers, versus on reviews focused on site-specific cancers.

Methodological limitations
This narrative review does not constitute a comprehensive systematic examination of every single systematic review and meta-analysis assessing the association between physical activity and cancer-related outcomes. Rather, this exercise examined only systematic reviews published in the last decade. Likewise, we only searched for reviews focused on cancers in general, and excluded reviews summarising the evidence on the associations between physical activity and site-specific cancers, given the volume of evidence available on this topic. This constitutes an important limitation as the term “cancer” refers to over 100 distinct disease, with specific etiology and mechanisms of action.

A critical examination of the evidence
<u>Physical activity and cancer prevention (incidence)</u>
Multiple large-scale epidemiologic reviews demonstrate that higher levels of aerobic leisure-time or total physical activity are associated with lower incidence of several cancers. Among the most recent high-quality systematic reviews was that by Mc. Tiernan et al., published in 2019,[99] and serving as the basis for the Scientific Report of the 2018 U.S. Physical Activity Guidelines. *The review reports “strong evidence”* for associations between highest vs lowest physical activity levels and reduced risk of bladder, breast, colon, endometrial, esophageal adenocarcinoma, renal, and gastric cancers (risk reductions on the order of ~10-20 %). A 2025 review by Kruk et al.[100] provides an update, including 22 new original studies, to the Mc. Tiernan review, and reports fundamentally consistent findings.

With regard to muscle-strengthening physical activity by Nascimento et al. (2021),[101] a systematic review with meta-analysis specifically addressed muscle-strengthening activity and cancer incidence/mortality found moderate evidence, drawn from two studies, for a protective effect for kidney cancer incidence (high vs low muscle-strengthening physical activity groups: HR 0.74; 95% CI: 0.56-0.98).

Physical activity and cancer survival (mortality)

Beyond prevention, there is growing evidence that physical activity levels either before or after a cancer diagnosis may improve survival among cancer patients/survivors.
A 2019 systematic review & meta-analysis by Friedenreich et al. of 136 studies (for pre- and post-diagnosis aerobic physical activity) found that for "all cancers combined," higher vs lower physical activity was associated with improved cancer-specific mortality, with stronger associations observed for post-diagnosis aerobic physical activity.[102] Likewise, a 2023 systematic review with meta-analysis focused on non-occupational physical activity and including data from over 30 million people, by Garcia et al. reported consistent results.[103] However, an important caveat is that the evidence available so far does not support added benefits of post-diagnosis physical activity among advanced cancer patients, per a review by Takemura et al. (2021),[104] suggesting that the benefits of physical activity for cancer survival occur mostly among patients in initial or intermediate stages of cancer. More research is needed to confirm this interpretation.

Physical activity and additional cancer survivorship outcomes

There is compelling evidence that physical activity (especially post-diagnosis) is associated with improved survival outcomes and quality of life in cancer survivors, particularly for common cancers (breast, colorectal, prostate) and for functional/psychosocial outcomes (strength, fatigue, quality of life). An umbrella review (meta-analyses of RCTs) of exercise interventions among cancer survivors found moderate to large beneficial effects on outcomes including cardiovascular fitness, muscle strength, health-related quality of life, fatigue and depression. An umbrella review (meta-analyses of RCTs) by Fuller et al. (2018)[105] of exercise interventions among cancer survivors found moderate to large beneficial effects on outcomes including cardiovascular fitness, muscle strength, health-related quality of life, fatigue and depression.

Physical activity and enhanced cancer treatment

There is a growing body of evidence suggesting that physical activity/exercise may do more than just improve general health and survivorship in cancer patients — it may enhance and/or improve tolerance to cancer treatment (chemotherapy, hormone therapy, possibly radiotherapy).[106] However, most of the research to date remains preclinical and mechanistic. At this stage, the evidence in humans is preliminary for direct improvement of tumour response or survival from the exercise-enhancement mechanism, and slightly stronger for enhanced treatment tolerance.

Gaps and limitations

Despite generally consistent evidence linking higher physical activity levels to lower cancer incidence and mortality, several important limitations constrain the strength and interpretation of this body of research. Most available studies are observational—primarily prospective cohort designs—which limits causal inference and leaves results vulnerable to residual confounding by correlated health behaviors, socioeconomic status, and adiposity. Physical activity is typically assessed through self-report using nonstandardized questionnaires across studies, leading to recall bias, misclassification, and limited comparability across studies. Moreover, most analyses rely on a single baseline assessment, failing to capture changes in activity over time or across the life course, and few studies incorporate objective measures such as accelerometry.

Further complexity arises from biological mechanistic heterogeneity across cancer sites. The mechanisms by which physical activity influences carcinogenesis—such as modulation of hormones, insulin signaling, inflammation, or immune function—likely differ by organ system, implying that the effective "dose" or intensity of activity for prevention and survival may vary by cancer type. Similarly, evidence regarding domain-specific effects remains limited: most epidemiologic studies focus on total or leisure-time physical activity, with relatively little analysis of occupational, transportation, or household domains, which may differ in physiological and behavioral impact. Muscle-strengthening activities, though included in physical activity guidelines, are rarely assessed separately, leaving their potential independent or synergistic effects on cancer incidence largely unknown.

Despite these limitations, the body of research is sufficiently robust and consistent to provide compelling evidence supporting the promotion of physical activity for cancer prevention, survival, and additional survivorship-related outcomes. Supplementary Table 11, below, provides a summary of a selection of recent systematic reviews on physical activity and cancer-related outcomes.

Supplementary Table 11. Overview of key recent systematic reviews on the associations between physical activity and cancer-related outcomes.

First author and year of publication	Focus of the systematic review (incidence, survival, other)	Key Results	Additional notes (considerations, caveats, limitations)
McTiernan et al. (2019)[99]	Incidence + survival (various cancers)	Found strong evidence for incidence reduction (~10-20%) for bladder, breast, colon, endometrium, esophageal adenocarcinoma, renal, gastric; moderate/limited evidence for survival in breast/colorectal/prostate (up to ~40-50% reduction).	Comprehensive, high quality review of evidence available until 2018. Uses grading of the evidence system (strong, moderate, and weak evidence)
Kruk et al. (2025)[100]	Incidence + survival (various cancers)	Evidence from 37 observational studies and 10 reviews were included in this systematic review; 22 studies reported the effect of physical activity on cancer incidence, and 15 studies on cancer mortality. The results support that higher levels of physical activity are associated with both lower cancer incidence rates and lower cancer mortality.	The systematic review covers studies published as of 2019, in an attempt to update the McTiernan et al. review. Thus, all the studies found are from the past few years, and confirm findings from prior research.
Nascimento et al. (2021)[101]	Incidence + survival of muscle-strengthening activities (MSA)	12 studies (≈1.3 m participants): MSA associated with 26% lower incidence of kidney cancer (HR 0.74, 95% CI 0.56-0.98) but not other cancers; for total cancer mortality: HR ~0.87 (95% CI 0.73-1.02) for highest vs lowest MSA; ≥2x/week vs <2x/week HR ~0.81 (95% CI 0.74-0.87).	Focus on strengthening rather than general PA; limited number of studies; heterogeneity; mainly observational.
Friedenreich et al. (2019)[102]	Survival (all-cancers + site-specific)	136 studies: highest vs lowest PA → cancer-specific mortality HR ≈ 0.82 (95% CI 0.79-0.86) for pre-diagnosis, and HR ≈ 0.63 (95% CI 0.53-0.75) for post-diagnosis PA, for all cancers combined. Stronger effects for breast/colorectal (post-diagnosis HR ~0.58-0.63 vs pre ~0.80-0.86).	Large meta-analysis, broad scope. Limitations: observational studies predominated, heterogeneity in PA assessment, possible confounding.
Takemura et al. (2021)[104]	Survival in advanced cancer (post-diagnosis PA)	11 studies: higher PA was *not* significantly associated with lower earlier mortality in advanced cancer patients (lnHR = –0.18, 95% CI –0.36 to 0.01)	Focused on advanced disease; few studies; heterogeneity high; suggests less robust evidence for PA benefit in advanced cancer stage.
Garcia et al. (2023)[103]	Survival (various cancers)	196 articles were included, covering 94 cohorts with >30 million participants. Non-occupational physical activity was found to be associated with lower risk of cancer mortality (RR at 8.75 mMET-hours/week: 0.85, 95% CI 0.81 to 0.89).	Robust systematic review with meta-analysis combining data from multiple prospective cohorts and a large sample size. Excludes occupational domain.
Lacombe et al. (2019)[107]	Survival (cancer + CVD) in association to PA in combination with additional behavioural risk factors	PA combined with another behavioural risk factor influences cancer/all-cause mortality; specific cancer site results are less detailed. Interactions between physical activity and other behavioural risk factors are somewhat complex and require further research.	Broader lifestyle context; less specific to PA-only effect on cancer survival.
Plinsinga et al. (2023)[108]	Other: pain among cancer patients and survivors	71 studies reported in 74 papers were eligible for inclusion. The overall meta-analysis included 5877 participants and showed reductions in pain favouring exercise (standardised mean difference − 0.45; 95% confidence interval − 0.62, − 0.28).	Evidence graded low–very low; high heterogeneity.
Fuller et al. (2018)	Other: fatigue, quality of life, depression, fitness among cancer survivors.	65 review articles that reported a total of 140 independent meta-analyses. 139/140 meta-analyses suggested a beneficial effect of exercise, with higher effect sizes for cardiovascular and muscular fitness, and smaller yet significant effects for cancer-related fatigue, health-related quality of life and depression.	The quality of evidence was variable according to the GRADE scale, with most studies rated low or moderate quality.
Fernandez-Sanchez et al. (2024)	Other: life satisfaction among cancer survivors	Six controlled trials: exercise interventions improved life satisfaction (compared to usual care) in people with cancer/survivors.	Small number of studies included.

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