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Predictors of physical functioning after total hip arthroplasty: a systematic review

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ABSTRACT

Objective: The objective of this systematic review of the literature was to identify the predictors of functional outcome after total hip arthroplasty (THA).

Method: A systematic literature search in Web of Science, CINAHL, EMBASE and PubMed was conducted on 23 June 2015. The articles were selected based on their quality, relevance and measurement of the predictive factor. The level of evidence of all studies was determined using the GRADE rating scheme.

Results: The initial search resulted in 1092 citations. After application of the inclusion and exclusion criteria, 33 articles met our eligibility criteria and were graded. Included studies were classified as level of evidence low (11), moderate (17) or high (5). Of the included studies, 18 evaluated body mass index (BMI), 17 evaluated preoperative physical functions, 15 evaluated age, 15 evaluated gender and 13 evaluated comorbidity. There was strong evidence suggesting an association between BMI, age, comorbidity, preoperative physical functions and mental health with functional outcome after THA. There was weak evidence suggesting an association between quadriceps strength and education with functional outcome after THA. The evidence was inconsistent for associations with gender and socioeconomic status and functional outcome following THA. We found limited evidence suggesting that alcohol consumption, vitamin D insufficiency and allergies were predictors of functional outcome following THA.

Conclusions: We have identified multiple predictors of functional outcome after THA, which will enable general practitioners and orthopaedic surgeons to better predict the improvement in physical functioning for their patients with THA. They can use this information to provide patient-specific advice regarding the referral for THA and the expected outcomes after THA. Further research with consistent measurement tools, outcomes and duration of follow-up across studies is needed to confirm the influence of these factors.

Strengths and limitations of this study

- We have carried out a comprehensive and robust systematic review in accordance with the PRISMA guidelines.
- We included a range of patient-related predictors and did not limit ourselves to the most common predictors. This led to a broad overview of predictors evaluated.
- We screened a large number of literature sources, and all reviewing and data extraction was carried out by one author (LDB) and double checked by a second author (LWAHVB).
- Owing to the heterogeneity across studies regarding measurement tool, predictor and duration of follow-up we could not apply a meta-analysis.
- The predictors like quadriceps strength, education, socioeconomic status and alcohol consumption were reported only a few times and therefore conclusions cannot be reached.

INTRODUCTION

Total hip arthroplasty (THA) is a surgical procedure performed to reduce pain and improve function in patients with osteoarthritis (OA) of the hip. According to the Agency for Healthcare Research and Quality, more than 305 000 total hip replacements are performed each year in the USA.[1] Following THA, the majority of patients experience reductions in pain, improvements in function and better health-related quality of life.[2] However, not all patients achieve the same level of functional improvement after THA. Specifically, more than 30% of patients undergoing THA report moderate-to-severe activity limitations 2 years post-THA.[3] It is unclear which factors are associated with these limitations in function.[4 5]

In the previous decade, many studies have been published investigating the predictors of functional outcome after THA. Young *et al* published a systematic review on this topic in 1998. Since then considerable research has been published on predictors of functional outcome which justifies a new systematic review.[6] Therefore, we conducted a systematic review of predictors of mid-term and long-term functional outcome after THA.

METHODS

Registration

This systematic review is registered at Prospero (http://www.crd.york.ac.uk/PROSPERO/) with registry number CRD42015016929.

Selection criteria

Studies that met the following criteria were included in our review: (1) included patients undergoing a THA; (2) included physical functioning was an outcome measure; (3) had at least one variable that was considered as a predictor of physical functioning and (4) was written in English. We did not select a time period.

Search strategy

With the guidance of an independent medical librarian, we conducted a literature search through four medical databases: Web of Science; CINAHL; EMBASE and PubMed. This literature search was performed on 23 June 2015. In Web of Science we used the following search terms: TOPIC: (total hip arthroplasty) AND TOPIC: (predictor*). In CINAHL we searched for: (MM "Arthroplasty, Replacement, Hip") AND predictor*. In EMBASE we searched for: exp hip arthroplasty/exp prediction/or exp predictor variable/exp prognosis/or exp functional assessment/or exp treatment outcome/or exp daily life activity/. In PubMed we searched for ("Arthroplasty, Replacement, Hip"(Majr) OR "Hip Prosthesis"(Majr)) AND (predictor* OR risk Factor* OR risk assessment OR predictive value of tests OR prognostic factor* OR Prognostic*) AND (HOOS OR "hip disability and osteoarthritis outcome score" OR WOMAC OR "Western Ontario and McMaster Universities Arthritis Index" OR "Harris hip score" OR HHS OR SF-12 OR short form 12 OR SF 36 OR "short form 36" OR Trendelenburg OR TUG OR "timed up and go" OR "Oxford hip score" OR "IOWA hip score" OR "Functional recovery score" OR FRS OR AFI OR "Hospital for special surgery" OR AAOS OR "Charnley hip score" OR HSS OR LEGS OR "Mayo clinical hip score"). The results of these four different searches were combined in Reference Manager and duplicates were discarded.

Study selection

Two of the authors (LWAHVB and TP) independently screened the titles and abstracts of all the articles using the aforementioned selection criteria. Both reviewers screened the full-text articles of the articles found eligible in the first round. A third author (LDB) compared these results and in case of different opinions, a consensus was reached. The study selection procedure is schematically presented in figure 1.

Data extraction

One of the authors (LDB) extracted the data, which was double checked by a second author (LWAHVB). From each article, the following information was extracted: (1) predictor variable; (2) author; (3) year of publication; (4) level of evidence; (5) number of patients; (6) measurement tools used; (7) follow-up period; (8) significance level; (9) association between predictor variable and outcome measure; and (10) predictor level of measurement (table 1). The results were categorised by predictor variable.

Methodological quality assessment

The level of evidence of all studies was determined by one of the authors (LDB) using the GRADE rating scheme (http://www.gradeworkinggroup.org).

Measurement tools

We aimed to include all predictors mentioned in previous studies, and did not limit ourselves to the most common predictors. Some of the widely used measurement tools to define functional outcome are the Harris Hip Score (HHS),[7] Oxford Hip Score (OHS),[8 9] Short Form-36 (SF-36),[10] Lower Extremity Functional Scale (LEFS),[11] Timed Up and Go (TUG) test[12 13] and the Western Ontario and McMaster Universities OA Index (WOMAC).[14] We used all these measurement tools as outcome in this study.

Best evidence synthesis

A follow-up period up to 24 months was considered as 'short term' and a follow-up period of more than 24 months was considered as 'long term'. Results were divided into four categories of evidence: strong evidence: at least 60% of the studies, with a minimum of three studies, describing the same significant ($p<0.05$) association. Weak evidence: (1) only two studies describe the same significant association; (2) three studies describe the same association out of which two are significant and one is not significant ($p>0.05$). Limited evidence: (1) only one study available; (2) more studies were available of which none found a significant association. Inconsistent evidence: all other scenarios.[15] No conclusions can be drawn in this literature review when no or inconsistent evidence is available.

This systematic review conforms to the PRISMA statement.[16]

RESULTS

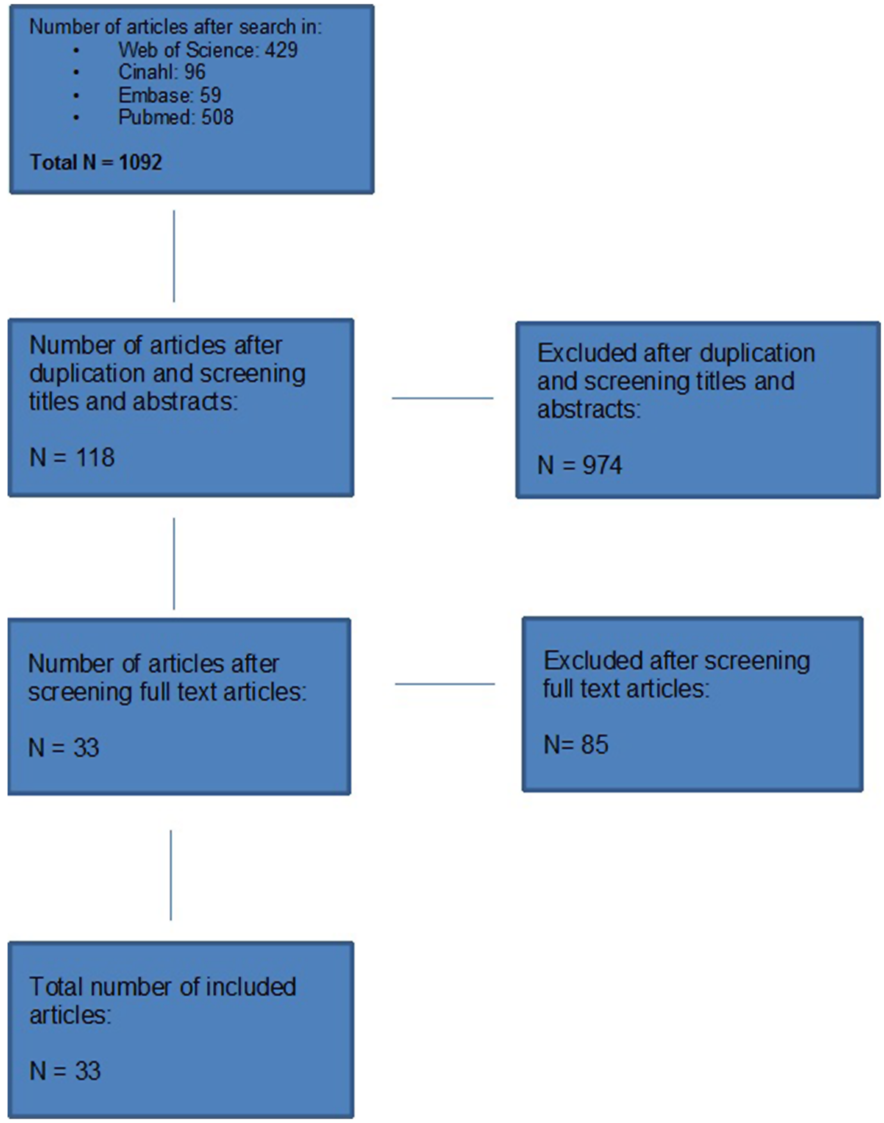
Selection and methodological quality

The initial search resulted in 1092 citations (figure 1) and 33 articles met our eligibility criteria. The articles included were designated as level of evidence low (11), moderate (17) or high (5; table 1)

Measures of functional outcome

Multiple outcome measures were used across these studies including the HHS, OHS, SF-36 physical function (PF), LEFS, TUG and the WOMAC score. The follow-up period ranged from 3 to 72 months with an average of 18 (SD 17) months (table 2).

Figure 1 Flow chart of the study selection procedure.



Predictive factors of functional outcome

Body mass index

Eighteen studies evaluated body mass index (BMI) as a potential predictor of functional outcome after THA[17–34] (table 3). A total of 14 432 patients were included in all articles concerning the impact of BMI, with a mean follow-up time of 22 months. The applied levels of measurement of BMI were continuous, dichotomous or categorical.

The measurement tools used to determine the functional outcome were the WOMAC score, HHS, OHS, LEFS, SF-12 PF and the ambulatory status. The classification of a high BMI ranged from >28 to >35 kg/m^2.

Of the 18 studies, 13 found a significant association.[17–19 22 23 25 27–31 33 34] Twelve studies evaluated the short-term functional outcome of which eight studies[17 20 22 25 28 30 33 34] found a significant negative association and one article had a significant positive association.[31] Of the seven studies evaluating the long-term functional outcome, five articles found a significant negative association.[18 19 23 27 29] Studies were designated as level of evidence low (5), moderate (9) or high (4).

Since more than 60% of the studies report a significant negative association, there is strong evidence of a negative association between BMI and short-term and long-term functional outcomes after THA. These results were consistent when we only considered the studies with high or moderate levels of evidence according to GRADE.

Age

Fifteen studies evaluated age as a possible predictor of functional outcome after THA[17 18 21 23 24 26–30 32 34–37] (table 4). A total of 9234 patients were included in all studies that identified age as a possible predictor, with a mean follow-up time of 19 months. The applied levels of measurement of age were continuous, dichotomous or categorical.

The measurements tools used to determine the functional outcome were the WOMAC score, HHS, OHS,

Table 1 Methodological quality of included studies

Study	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Grade
Kessler and Käfer[24]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Aranda Villalobos *et al*[31]	Observational study	Not serious	Not serious	Not serious	Not serious	None	Low
Nankaku *et al*[26]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Slaven[28]	Observational study	Not serious	Not serious	Not serious	Not serious	None	Low
Moran *et al*[25]	Observational study	NA	Not serious	Not serious	Not serious	Strong association	Moderate
Stevens *et al*[30]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Wang *et al*[32]	Observational study	Not serious	Not serious	Not serious	Not serious	None	Moderate
Dowsey *et al*[20]	Observational study	Serious	Not serious	Not serious	Not serious	Strong association	Low
Judge *et al*[33]	Observational study	Not serious	Not serious	Not serious	Not serious	Very strong association	High
Bergschmidt *et al*[17]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Jones *et al*[22]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Smith *et al*[29]	Observational study	Not serious	Not serious	Serious	Not serious	Strong association	Moderate
Judge *et al*[23]	Observational study	Not serious	Not serious	Not serious	Not serious	Very strong association	High
Bischoff *et al*[18]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Gandhi *et al*[21]	Observational study	Serious	Not serious	Not serious	Not serious	None	Low
Nilsdotter *et al*[27]	Observational study	Not serious	Serious	Not serious	Not serious	Strong association	Low
Davis *et al*[19]	Observational study	Not serious	Not serious	Not serious	Not serious	Very strong association	High
Hamilton *et al*[35]	Observational study	Not serious	Not serious	Not serious	Not serious	None	Low
Quintana *et al*[37]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Nilsdotter and Lohmander[36]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Dowsey *et al*[34]	Observational study	Not serious	Not serious	Not serious	Not serious	Very strong association	High
Lavernia, 2011[38]	Observational study	Serious	Not serious	Not serious	Not serious	Strong association	Low
Mahomed *et al*[39]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Vogl *et al*[43]	Observational study	Not serious	Serious	Not serious	Not serious	NA	Low
Clement *et al*[42]	Observational study	Not serious	Not serious	Not serious	Not serious	Very strong association	High
Johansson *et al*[40]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Fortin *et al*[41]	Observational study	Not serious	Not serious	Not serious	Serious	Strong association	Low
Badura-Brzoza *et al*[44]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Holstege *et al*[46]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Schafer *et al*[47]	Observational study	Not serious	Not serious	Not serious	NA	Strong association	Low
Graves *et al*[48]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate
Lavernia, 2014[49]	Observational study	Not serious	Not serious	Not serious	NA	None	Low
Lavernia *et al*[45]	Observational study	Not serious	Not serious	Not serious	Not serious	Strong association	Moderate

High: true effect lies close to the estimate of the effect.
Moderate: true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low: true effect may be substantially different from the estimate of effect.
Very low: true effect is likely to be substantially different from the estimate of effect.
GRADE, Grading Recommendations Assessment Development and Evaluation; NA, not applicable.

Table 2 Characteristics of all included studies

Author, year, nr	Age baseline	N of pts	Female (n, %)	Inclusion criteria	Follow-up time	Measurement tool
Badura-Brzoza, 2009, 42	61 (54–75)	156	59 (58%)	Primary THA, OA	6 months	SF-36 PF
Bergschmidt, 2010, 113	66 (58–74)	100	48 (50%)	Primary THA, OA	6–12–24 months	HHS WOMAC SF-12
Bischoff, 2004, 51	73.1 (65–93)	922	60%	OA, primary THA >65 years	3 years	WOMAC PF
Clement, 2011, 101	68.1 (65–74)	1312	NA	Primary OA, THR	12 months	OHS SF-12
Davis, 2011, 100	69 (34–96)	1617	994	Cemented THA	5 years	HHS SF-36 PF
Dowsey, 2010, 32	68.6/67/65.6	471	60.70%	Primary THA OA	12 months	HHS SF-12 PF
Dowsey, 2014, 15	68.4	835	60.10%	Primary THA	12 months	SF-12
Fortin, 2002, 145	65.7	222	59%	Primary THA OA	2 years	WOMAC SF-36
Hamilton, 2012, 17	68.1	1410	57.20%	Primary THA OA	6–12 months	OHS SF-12
Gandhi, 2010, 30	63.2 (13.7)	636	53.50%	<18 years, primary OA	3.3 years	WOMAC SF-36 PF
Graves, 2014, 29	59.5	459	61.00%	THA OA	10. 4 months	WOMAC SF-36
Holstege, 2011, 102	72.7 (6.8)	55	41 (74,5)	THA OA	3 months	WOMAC PF
Johansson, 2010, 114	67 (7)	75	36 (48%)	THA OA	6–12–24 months	HHS WOMAC SF-36
Jones, 2012, 90	68.2 (10.9)	231	138 (60%)	Primary THA	6–36 months	WOMAC
Judge, 2013, 14	70	1431	887 (62%)	OA	1–6 years	OHS
Kessler, 2007, nr 131	63.6	76	44.8 (59%)	THA OA	3 months	WOMAC
Lavernia, 2014, 73	70	60	48 (80%)	Primary THA	3–24 months	QWB-7 SF-36 PF WOMAC HHS
Lavernia, 2013, 81	62	191	70	Primary THA	12 months	WOMAC SF-36
Lavernia, 2011, 103	61 (15)	532	59%	THA	6–7 years	SF-26 HHS WOMAC
Mahomed, 2002, 149	66 (9)	103	57 (55%)	THA OA	6 months	WOMAC PF SF-36 PCS
Moran, 2005, 136	68	749	61%	Primary THA	6, 18 months	HHS
Nankaku, 2013, 83	60.4	204	173	THA OA	6 months	Ambulatory status
Nilsdotter, 2002, 147	71	148	83	THA OA	3–6–12 months	WOMAC SF-36
Nilsdotter, 2003, 52	71	211	106	Primary THA	3, 6 years	WOMAC PF
Quintana, 2009, 35	69.1	788	381 (48%)	Primary THA OA	6–24 months	SF-36 PF WOMAC
Schafer, 2010, 110	61	1007	55%	Primary THA	6 months	WOMAC
Slaven, 2012, 15	68.2 (8.2)	40	22 (55%)	Primary THA	6 months	LEFS
Smith, 2012, 92	68.5 (9.9)	1683	NA	Primary THA	3 years	HHS
Stevens, 2012, 22	70.3 (8.2)	653	74.20%	Primary THA, OA	52. 4 weeks	WOMAC
Villalobos, 2012, 80	62.39 (13.6)	63	35 (55.55%)	Primary THA	3 months	HHS OHS WOMAC SF-12 PF
Vogle, 2014, 108	68	321	58%	Primary THA	6 months	WOMAC
Wang, 2010, 107	61.65	97	62.40%	OA/osteonecrosis	3–12–24 months	WOMAC

HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; N of pts, number of patients; NA, not applicable; OHS, Oxford Hip Score; PCS, physical component summary scale; PF, physical function; QWB; quality of well-being index; SF-36 PF, Short Form 36 physical function; THA, total hip arthroplasty; THR, total hip replacement; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

Table 3 Studies reporting BMI as possible predictor of functional outcome after THA

Author, year	Grade	N of pts	Measurement tool	FU period (months)	Significance Level (p value)	Association	Predictor level of measurement
Kessler, 2007	Moderate	76	WOMAC	ST (3 m)	0.49	No	Cont (BMI)
Villalobos, 2012	Low	63	SF-12 PCS	ST (3 m)	**0.004***	Pos	Dich
			WOMAC		**0.041***	Pos	(1: BMI>28 2: BMI ?28)
			HHS		0.793*	No	
			OHS		0.428*	No	
Nankaku, 2013	Moderate	204	Ambulatory status	ST (6m)	0.06	No	Cont (BMI)
Slaven, 2012	Low	40	LEFS	ST (6 m)	**NA**	Neg	Dich (1: BMI>34 2: BMI ?34)
Moran, 2005	Moderate	749	HHS	ST (6 m)	**0.02**	Neg	Cont (BMI)
				ST (18 m)	**0.001**	Neg	
Stevens, 2012	Moderate	653	WOMAC	ST (12 m)	**0.001**	Neg	Cont (BMI)
Wang, 2010	Moderate	97	WOMAC	ST (12 m)	0.11	No	Cont (BMI)
Dowsey, 2010	Low	471	HHS	ST (12 m)	**<0.01**	Neg	Cat (3)
			SF-12 PCS		**0.05**	Neg	(1: BMI<30 2: BMI 30–39 3: BMI≥40)
Dowsey, 2014	High	835	HHS	ST (12 m)	**<0.0001**	Neg	Cont (BMI)
Judge, 2014	High	4413	OHS	ST (12 m)	**0.003**	Neg	Cat (5) (1: BMI 18.5–25 2: BMI 25–30 3: BMI 30–35 4: BMI 35–40 5: BMI>40)
Bergschmidt, 2010	Moderate	100	HHS	ST (24 m)	**0.007**	Neg	Cat (3) (1: BMI<26 2: BMI 26–29 3: BMI>29)
Jones, 2012	Moderate	231	WOMAC	ST (6 m)	**0.001**	Neg	Dich
				LT (36 m)	No	No	(1: BMI>35 2: BMI ?35)
Smith, 2012	Moderate	1683	HHS	LT (36 m)	**<0.01**	Neg	Cont (BMI)
Judge, 2013	High	1431	OHS	LT (36 m)	**<0.001**	Neg	Cont (BMI)
Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	**NA**	Neg	Cont (BMI)
Gandhi, 2010	Low	636	WOMAC	LT (39 m)	0.06	No	Cont (BMI)
Nilsdotter, 2003	Low	211	WOMAC PF	LT (42 m)	**0.03**	Neg	Cont (BMI)
Davis, 2011	High	1617	HHS	LT (60 m)	**<0.001**	Neg	Cont (BMI)

All significant results are bold; studies that used change in function as outcome are marked with *.
BMI, body mass index; Cat, categorical; Cont, continuous; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; THA, total hip arthroplasty; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

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Table 4 Studies reporting age as possible predictor of functional outcome after THA

Author, year	Grade	N of pts	Measurement tool	FU period (months)	Significance Level (p value)	Association	Predictor level of measurement
Kessler, 2007	Moderate	76	WOMAC	ST (3 m)	**0.03**	Neg	Cont (age)
Nankaku, 2013	Moderate	204	Ambulatory status	ST (6 m)	Yes	Neg	Dich (1: age >67.5 2: age ?67.5)
Slaven, 2012	Low	40	LEFS	ST (6 m)	No	No	Dich (1: age >68.5 2: age ?68.5)
Hamilton, 2012	Low	1410	OHS	ST (6 m)	X	No	Cont (age)
			SF-12	ST (12 m)	X	No	
Quintana, 2009	Moderate	788	WOMAC PF	ST (6 m)	0.41	No	Dich
				ST (24 m)	**0.001**	Neg	(1: age >70 2: age ?70)
Stevens, 2012	Moderate	653	WOMAC	ST (12 m)	**0.01**	Neg	Cont (age)
Wang, 2010	Moderate	97	WOMAC	ST (12 m)	No	No	Cont (age)
Dowsey, 2014	High	835	HHS	ST (12 m)	**<0.0001**	Neg	Cont (age)
			SF-12 PCS		**0.003**	Neg	
Nilsdotter, 2002	Moderate	148	WOMAC PF	ST (12 m)	**0.004**	Neg	Dich
			SF-36		**0.002**	Neg	(1: age >72 2: age ?72)
Bergschmidt, 2010	Moderate	100	HHS	ST (12 m)	>0.097	No	Cat (3)
			WOMAC		>0.097	No	(1: age <60 2: age 60–69 3: age >69
			SF-12		>0.097	No	
Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	X	No	Dich (1: age >75 2: age ?75)
Judge, 2013	High	1431	OHS	LT (36 m)	**NA**	Neg	Cat (3) (1: age <50 2: age 50–60 3: age >60
Smith, 2012	Moderate	1683	HHS	LT (36 m)	**<0.001**	Neg	Cont (age)
Nilsdotter, 2003	Low	211	WOMAC PF	LT (43 m)	**0.002**	Neg	Cont (age)
Gandhi, 2010	Low	636	WOMAC	LT (39 m)	**<0.05**	Neg	Cont (age)
			SF-36		**<0.05**		

All significant results are bold.
BMI, body mass index; Cat, categorical; Cont, continuous; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; THA, total hip arthroplasty; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

SF-36 PF, SF-12 PF and the ambulatory status. Different classifications of greater age were used, ranging from >60 to >75 years.

Of the 15 studies, 10 found a significant association.[21 23 24 26 27 29 30 34 36 37] Ten studies evaluated the short-term functional outcome of which six studies found a significant negative association.[24 26 30 34 36 37] The other four studies did not find a significant association. Of the six studies evaluating the long-term functional outcome, five studies found a significant negative association.[21 23 29 36 37] Studies were designated as level of evidence low (4), moderate (9) or high (2).

Since more than 60% of the studies report a significant negative association, there is strong evidence of a negative association between high age and short-term and long-term functional outcomes after THA. These results were consistent when we only considered the studies with high or moderate levels of evidence according to GRADE.

Gender

Fifteen studies evaluated gender as a possible predictor of functional outcome after THA[17 18 21 22 24 26–30 32 34 36–38] (table 5). A total of 7156 patients were included in all studies that evaluated gender as a possible predictor, with a mean follow-up time of 23.3 months. The measurement tools used to determine the functional outcome included the WOMAC score, HHS, LEFS, SF-36 and the ambulatory status.

Of the 15 studies, 7 found a statistically significant association between preoperative physical function and functional outcome.[21 28–30 32 37 38] Nine studies evaluated the short-term functional outcome of which four studies found a significant association.[28 30 32 37] Six studies evaluated the long-term functional outcome of which three found a significant association.[21 29 38] All studies were designated as level of evidence low (5), moderate (9) or high (1).

In four of the seven studies with a significant outcome, being male predicted a better outcome[29 30 32 37] whereas

Table 5 Studies reporting gender as possible predictor of functional outcome after THA

Author, year	Grade	N of pts	Measurement tool	FU period (months)	Significance Level (p value)	Association	Predictor level of measurement
Kessler, 2007	Moderate	76	WOMAC	ST (3 m)	NA	No	Dich (1: men 2: woman)
Nilsdotter, 2002	Moderate	148	WOMAC SF-36	ST (3 m) ST (12 m)	0.7	No	Dich (1: men 2: woman)
Nankaku, 2013	Moderate	204	Ambulatory status	ST (6 m)	0.10	No	Dich (1: men 2: woman)
Slaven, 2012	Low	40	LEFS	ST (6 m)	**0.039**	Pos, woman	Dich (1: men 2: woman)
Quintana, 2009	Moderate	788	SF-36 PF	ST (6 m) ST (24 m)	**NA** NA	Pos, men No	Dich (1: men 2: woman)
Bergschmidt, 2010	Moderate	100	HHS	ST (12 m)	NA	No	Dich (1: men 2: woman)
Stevens, 2012	Low	653	WOMAC	ST (12 m)	**0.002**	Pos, men	Dich (1: men 2: woman)
Dowsey, 2014	High	835	HHS	ST (12 m)	0.06	No	Dich (1: men 2: woman)
Wang, 2010	Moderate	97	WOMAC	ST (16.8 m)	**0.0001**	Pos, men	Dich (1: men 2: woman)
Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	No	No	Dich (1: men 2: woman)
Jones, 2012	Moderate	231	WOMAC	LT (36 m)	0.118	No	Dich (1: men 2: woman)
Smith, 2012	Moderate	1683	HHS	LT (36 m)	**<0.001**	Pos, men	Dich (1: men 2: woman)
Gandhi, 2010	Low	636	WOMAC SF-36 PF	LT (39 m)	No **<0.05**	No Pos, woman	Dich (1: men 2: woman)
Lavernia, 2011	Low	532	WOMAC PF	LT (42 m)	**<0.001***	Pos, woman	Dich (1: men 2: woman)
Nilsdotter, 2003	Low	211	WOMAC PF	LT (66 m)	0.37	No	Dich (1: men 2: woman)

All significant results are bold; studies that used change in function as outcome are marked with *.
BMI, body mass index; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; THA, total hip arthroplasty; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

three studies reported being female as a predictor of better functional outcome.[21 28 38] This demonstrates inconsistent evidence for an association between gender and functional outcome after THA.

Preoperative physical function

Seventeen studies evaluated preoperative physical function as a possible predictor of functional outcome after THA[17 23 25–29 32 34–37 39–43] (table 6). A total of 9689 patients were included in all studies that evaluated preoperative physical function, with a mean follow-up time of 16 months. The applied levels of measurement of preoperative physical function were continuous, dichotomous or categorical.

The WOMAC score[14] was the measurement tool most used to determine the preoperative physical function.[17 27 32 36 37 39–41 43] Other measurement tools used were the HHS, TUG, OHS, SF-36, SF-12 and the ambulatory status.

Of the 17 studies, 16 found a statistically significant correlation between preoperative physical function and the functional outcome. Fourteen studies evaluated the short-term outcome of which 13 reported a significant association. Three studies evaluated the long-term outcome; all three found a significant association. The only study that did not report a significant association, was a study on a small patient group that used the TUG to determine the preoperative physical function.[28] Studies were designated as level of evidence low (5), moderate (9) or high (3).

As more than 60% of the studies report a significant negative association, there is strong evidence of a short-term and long-term association between the preoperative physical function and the functional outcome after THA.

Comorbidity

Thirteen studies evaluated comorbidity as a possible predictor of functional outcome after THA (table 7). A total of 9363 patients were included in all studies that evaluated comorbidity as a possible predictor, with a mean follow-up time of 23.3 months. The applied levels of measurement of preoperative status were continuous, dichotomous or categorical.

The measurement tools used to determine the functional outcome were the WOMAC score, HHS, LEFS, SF-36 and the ambulatory status. Most studies used the number of comorbidities or American Society of Anesthestiologists (ASA) grade as predictor of functional outcome. Other studies used the presence of a specific comorbidity as a predictor like cardiac disease, coronary heart disease and thromboembolism.

Of the 13 studies, 11 found a significant negative association.[18 21 22 25 27 29 30 32–34 37 39 42] Seven studies evaluated the short-term outcome of which six reported a significant negative association.[22 23 25 30 32 34 39 42] Six studies evaluated the long-term outcome, of which five found a significant negative association.[18 21–23 29] All articles were designated as level of evidence low (2), moderate (8) or high (3).

Since more than 60% of the studies report a significant negative association, there was strong evidence of a negative association between comorbidities and short-term and long-term functional outcomes after THA.

Other predictors

The predictors that were evaluated in five studies or less are displayed in table 8.

Five studies evaluated *mental health* as a possible predictor of functional outcome after THA, with a total of 3563 patients.[18 23 34 37 44] All four studies evaluating the short-term functional outcome found a significant positive association.[23 34 37 44] Both studies that evaluated the long-term outcome found a significant positive association. Since more than 60% of the studies report a significant positive association, there is strong evidence of an association between good mental health and better short-term physical function outcome after THA. Since only two studies evaluated the long-term outcome, this evidence is weak.

Two studies evaluated *alcohol consumption* as a predictor of functional outcome.[18 45] Neither of them found a significant result and therefore none show evidence of an association. The two studies evaluating quadriceps strength as a possible predictor[26 46] looked at the short-term functional outcome and both found a significant association. Therefore, the evidence for an association is weak.

All three studies that evaluated educational level as a possible predictor found a significant association.[18 39 47] Two studies evaluated the short-term outcome and both found a significant association.[39 47] One study evaluated the long-term effect and found a significant association.[18] All three studies used the WOMAC score to measure the functional outcome. These results show weak evidence for a short-term association, and incomplete evidence for a long-term association.

One study reported *socioeconomic status* (SES) as a predictor, using the SES score as measurement tool.[34] They did not find a significant result and therefore show limited evidence of an association.

The influence of having more than three *allergies* on the short-term functional outcome was reported in one study.[48] Patients with allergies had diminished improvements on SF-36 PCS and WOMAC scores 6.5 months after THA. There was limited evidence of an association between having more than three allergies and functional outcome.

Vitamin D insufficiency as a predictor of functional outcome after THA was evaluated in one study.[49] A preoperative 25-hydroxyvitamin D3 plasma level of under 30 ng/mL, predicted a worse HHS 11 months post-operative. Since no other studies evaluated vitamin D insufficiency as a possible predictor, this result shows limited evidence of an association.

Table 6 Studies reporting preoperative physical function as possible predictor of functional outcome after THA

Author, year	Grade	N of pts	Measurement tool	FU period (months)	Significance Level (p value)	Association	Predictor level of measurement
Quintana, 2009	Moderate	788	WOMAC PF SF-36 PF	ST (6 m)	**<0.001**	Yes	Cont (WOMAC+SF-36)
Slaven, 2012	Low	40	TUG	ST (6 m)	NA	No	Dich (successful/unsuccessful)
Mahomed, 2002	Moderate	103	WOMAC PF+P SF-36 PF	ST (6 m)	**<0.05** **<0.05**	Yes	Cont (WOMAC+SF-36)
Hamilton, 2012	Low	1410	OHS SF-12	ST (6 m) ST (12 m)	Yes	Yes	Cont (OHS)
Nankaku, 2013	Moderate	204	Ambulatory status ST (6 m)	**NA**	Yes	Dich (TUG score 10)	
Vogl, 2014	Low	281	WOMAC	ST (6 m)	**NA**	Yes	Cont (WOMAC)
Bergschmidt, 2010	Moderate	100	WOMAC SF-36	ST (12 m)	<0.022 0.003	Yes	Cat (3) 1: HHS<48 2: HHS 48–59 3: HHS>59
Clement, 2010	High	1312	OHS SF-12	ST (12 m)	**0.001***	Yes	Cont (OHS)
Johansson, 2010	Moderate	75	HHS WOMAC SF-36	ST (12 m)	**?0.006** **<0.001** **?0.005**	Yes Yes Yes	Cat (3) 1: HHS<45 2: HHS 45–55 3: HHS>55
Nilsdotter, 2002	Moderate	148	WOMAC SF-36	ST (12 m)	**<0.0001**	Yes	Dich Low quartile vs high quartile WOMAC
Dowsey, 2014	High	835	HHS	ST (12 m)	**<0.0001**	Yes	Cont (HHS)
Wang, 2010	Moderate	97	WOMAC	ST (16.8 m)	**0.0001**	Yes	Cont (WOMAC PF)
Moran, 2005	Moderate	749	HHS	ST (18 m)	**NA**	Yes	Cont
Fortin, 2002	Low	222	WOMAC SF-36	ST (24 m)	**NA** **NA**	Yes Yes	Dig (1: high WOMAC 2: low WOMAC)
Smith, 2012	Moderate	1683	HHS	LT (36 m)	**<0.001**	Yes	Cont (HHS)
Nilsdotter, 2003	Low	211	WOMAC PF	LT (42 m)	**0.007**	Yes	Dich Low quartile vs high quartile SF-36 PF
Judge, 2013	High	1431	OHS	LT (60 m)	**<0.001**	Yes	Cont (OHS)

All significant results are bold.
BMI, body mass index; Cat, categorical; Cont, continuous; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; THA, total hip arthroplasty; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

Table 7 Studies reporting comorbidity status as possible predictor of functional outcome after THA

Author, year	Grade	N of pts	Measurement tool	FU period (months)	Significance level (p value)	Association	Predictor level of measurement
Quintana, 2009	Moderate	788	WOMAC PF SF-36 PF	ST (6 m)	NA NA	No	Cat (3) 1: 0 comorbidities 2: 1–2 comorbidities 3: >2 comorbidities
Mahomed, 2002	Moderate	103	WOMAC PF+P	ST (6 m)	**<0.05**	Neg	Cont (number of comorbidities)
Moran, 2005	Moderate	749	HHS	ST (6 m) ST (18 m)	**NA**	Neg	Dich (presence of coronary heart disease and previous thromoembolism)
Stevens, 2012	Moderate	653	WOMAC	ST (12 m)	**0.01**	Neg	Cat (3) 1: 0 comorbidities 2: 1–2 comorbidities 3: >2 comorbidities
Clement, 2010	High	1312	OHS SF-12	ST (12 m)	**0.01**	Neg	Cont (number of comorbidities)
Dowsey, 2014	High	835	HHS	ST (12 m)	**0.0001**	Neg	Cont (age-adjusted CCI)
Wang, 2010	Moderate	97	WOMAC	ST (16.8 m)	**0.0246**	Neg	Dich (1: >0 comorbidities 2: 0 comorbidities)
Jones, 2012	Moderate	231	WOMAC	LT (36 m)	**0.012**	Neg	Dich (1; 0 cardiac diseases 2: >0 cardiac diseases)
Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	**NA**	Neg	Dich (1; >2 chronic diseases 2. 0–1 chronic diseases)
Smith, 2012	Moderate	1683	HHS	LT (36 m)	**<0.001**	Neg	Cont (ASA grade)
Gandhi, 2010	Low	636	WOMAC SF-36 PF	LT (39 m)	**<0.05**	Neg	Cont (number of comorbidities)
Nilsdotter, 2003	Low	211	WOMAC PF	LT (42 m)	0.08	No	Dich (1: >1 comorbidities 2: 0–1 comorbidities)
Judge, 2013	High	1431	OHS	LT (60 m)	**0.001**	Neg	Cont (number of comorbidities)

All significant results are bold.
BMI, body mass index; Cat, categorical; CCI, Charlson comorbidity index; Cont, continuous; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; THA, total hip arthroplasty; WOMAC, Western Ontario and Mcmaster Universities Osteoarthritis Index.

Table 8 All predictors that are evaluated in five studies or less

Predictor	Author, year	Grade	N of pts	Measurement tool	FU-period (months)	Significance level (p value)	Association	Predictor level of measurement
Mental health	Badura-Brzoza, 2009	Moderate	102	SF-36 PCS	ST (6 m)	**0.005**	Neg	Cont (anxiety as a trait)
	Quintana, 2009	Moderate	788	SF-36 PF WOMAC P	ST (6 m) ST (24 m)	**<0.001** **0.002**	Yes	Cont (SF-36 MH score)
	Dowsey, 2014	High	835	HSS	ST (12 m)	**<0.0001**	Yes	Cont (SF-12 MH score)
	Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	**NA**	Yes	Dich (1: >60 pts on the SF-36 MH score 2: ?60 pts on SF-36 MH score)
	Judge, 2013	High	916	OHS	ST (12 m) LT (60 m)	**0.045**	Yes	Cont (SF-36 MH score)
Alcohol consumption	Bischoff, 2004	Moderate	914	WOMAC PF	LT (36 m)	**NA**	No	Dich (1: >1 alcoholic drinks per day 2: 0–1 alcoholic drinks per day)
	Lavernia, 2014	Low	191	WOMAC	LT (72 m)	**NA**	No	Cat (3) (1: non-drinkers 2: occasional drinkers 3: moderate drinkers)
Quadriceps strength	Holstege, 2011	Moderate	55	WOMAC PF	ST (3 m)	**0.004**	Pos	Cont (knee extensor strength)
	Nankaku, 2013	Moderate	204	Ambulatory status	ST (6 m)	**NA**	Pos	Dich (1: >1.25 N m/kg 2: ?1.25 m/kg knee extensor strength)
Education	Schafer, 2010	Low	1007	WOMAC	ST (6 m)	**NA**	Pos	Dich (1; >12 years school 2: <9 years school)
	Mahomed, 2002	Moderate	103	WOMAC PF+P	ST (6 m)	**0.007**	Pos	Cont (level of education)
	Bischoff, 2004	Moderate	922	WOMAC PF	LT (36 m)	**NA**	Pos	Dich (1: college education 2: less than college education)
Socioeco nomic status	Dowsey, 2014	High	835	HHS	LT (12 m)	0.63	No	Cont (SES score)
Allergies	Graves, 2014	Moderate	459	WOMAC PF SF-36 PCS	ST (6.5 m)	**0.04** **0.0002**	Neg	Dich (>3 allergies)
Vitamin D insufficiency	Lavernia, 2013	Moderate	60	HHS WOMAC	ST (11 m)	**0.002** 0.478	Neg	Dich (25-hydroxyvitamin D3) (1; >30 ng/mL 2: <30 ng/mL)

All significant results are bold.
BMI, body mass index; Cat, categorical; Cont, continuous; Dich, dichotomous; FU, follow-up; HHS, Harris Hip Score; LEFS, Lower Extremity Functional Scale; LT, long-term; N of pts, number of patients; NA, not applicable; Neg, negative; OHS, Oxford Hip Score; PCS, physical component summary scale; Pos, positive; SF-36 PF, Short Form 36 physical function; ST, short-term; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

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DISCUSSION

In this systematic literature review, we sought to provide a clear overview of a range of patient-related predictors of functional outcome after THA.

Key findings

Our review found strong evidence of an association of BMI, age, comorbidity, preoperative physical function and mental health with functional outcome after THA. Weak evidence was found for the predictors like quadriceps strength and education. Inconsistent evidence was found for the predictors like gender and SES. Limited evidence was found for the predictors like alcohol consumption, vitamin D insufficiency and allergies.

In our review, 13 studies found a significant negative association between BMI and functional outcome after THA. A prior review of Young *et al*[6] found the same significant negative association. Although the review of Young *et al* and our current review come to the same conclusion, the clinical impact of this outcome is still questionable. A large study by Judge *et al*[33] showed a small significant correlation between high BMI and worse functional outcome, but concluded that the total improvement in function outweighs the small lack of improvement caused by high BMI.

Although our review shows strong evidence of an association between BMI and functional outcome, different classifications of high BMI were used. Owing to these different classifications, it is difficult to define a specific BMI that predicts who will do well after THA. We could not conduct a meta-analysis since different classifications of BMI were used and there was heterogeneity in outcome instruments. Therefore, future research on the impact of BMI should use clearly defined outcomes that are consistent across studies.

In our review, 8 of the 14 studies found an association between higher age and poorer functional outcome; therefore, age is an important factor predicting functional outcome. Some articles used a linear regression analysis for age. When looking at age, it is interesting to see the effect of high age, and also of low age. Therefore, linear regression analysis might not be the best statistical analysis with variables as age or BMI. There is no consensus among studies about what specific age limit is recommended for THA. This current review shows inconclusive evidence of an association between gender and functional outcome because 6 out of 14 studies found a statistically significant result.

Three studies reported being female led to a better functional outcome.[21 28 38] The other four significant articles found the opposite result where being male had a positive association with functional outcome after THA.[29 30 32 37] The results are contradictory and the differences may be attributable to confounding factors.

Preoperative physical function was found to be a strong predictor of long-term functional outcome. With the exception of one study reporting the TUG test as an outcome, better preoperative physical function was consistently associated with better long-term physical function.[28] This might be due to the use of TUG score as measurement tool.[28] The WOMAC score was the measurement tool most used to define the preoperative status (nine times).[17 27 32 36 37 39–41 43] Other preoperative measurement tools that were good predictors of functional outcome were the HHS, OHS, SF-12 PF, SF-36 PF and the ambulatory status.

Of the 13 studies that evaluated comorbidity as a possible predictor of functional outcome, 11 found a significant negative association.[18 21–23 25 29 30 32 34 37 39 42] Comorbidity can be measured in several ways, for example, the number of comorbidities, the presence of a specific comorbidity, the Charlson index[50] and the Elixhauser comorbidity measure.[51] Comorbidities can affect the true functional outcome after THA but can also affect the score on the measurement tool. For example, if a patient is unable to walk to the grocery store after a THA due to a lung disease, his functional outcome score will be lower despite a possible good functioning total hip. Except for one article, all studies found a significant negative effect. Therefore, having comorbidities can be seen as a predictor of negative functional outcome.

All five studies that evaluated mental health as a predictor of functional outcome found a statistically significant positive association. Four of these studies used SF-36 MH[52] as the measurement tool to measure mental health.[18 23 34 37] These results show strong evidence of a positive association between mental health and short-term functional outcome after THA. The two studies reporting quadriceps strength as a predictor had both small sample sizes which can affect the external validity of the studies.[26 46] Therefore, this evidence is weak and more research must be carried out on the effect of quadriceps strength.

Three studies evaluated education as predictor of functional outcome. Mahomed *et al*[39] and Bischoff *et al*[18] used the level of school education as a predictor, and Schäfer *et al*[47] used years of education as a predictor. Since education is in part a surrogate of SES, this might also indicate that low SES is a factor associated with poor functional outcome. Dowsey *et al*[34] however did not find a correlation between SES and functional outcome. Future research is needed on various components of SES to specify the impact on functional outcome. As only one study evaluated each of the allergies[48] and vitamin D insufficiency[49] as possible predictors of functional outcome, no conclusions can be drawn.

Previous systematic reviews

The previous systematic review of Young *et al* concluded that important research remained to be done to examine the magnitude and interaction of patient factors on the outcome of THA.[6] The review of Young *et al* used only one database (MEDLINE) and is more than 15 years old. Young *et al* also looked at implant survivorship. In our systematic review, we used multiple databases (Web of Science, CINAHL; EMBASE and PubMed) and reported only patient-related predictors evaluated in the literature.

Strengths and limitations

We included a range of patient-related predictors and did not limit ourselves to the most common predictors. This led to a broad overview of predictors evaluated. The reason we could not apply a meta-analysis is because of the heterogeneity across studies regarding measurement tools, predictors and duration of follow-up. Not all studies used in this review adjusted their outcomes for potential confounders. Therefore, some outcomes may be due to confounding factors. A limitation of our review is that we looked at functional outcome without including pain. Some patients will not see an improvement in their function after THA, but will lose the hip-related pain. For this reason especially people with a high BMI and older age can benefit from THA, without improving the function of the hip. Some predictors such as quadriceps strength, education, SES and alcohol consumption are reported only a few times and therefore conclusions cannot be reached. More research in large data sets is needed to draw definitive conclusions on these predictors.

Implications for practice

Our review provides a clear overview of the current literature on the predictors for physical functioning after THA. Orthopaedic surgeons and general practitioners can use this information to predict the improvement in physical functioning of their patients and it enables them to provide patient-specific advice on THA.

Implications for future research

In the future, we suggest studies that evaluate possible predictors of functional outcome after THA to use similar measurement tools, outcomes and durations of follow-up. In that way a meta-analysis can be applied and the influence of these factors can be specified.

CONCLUSION

This review shows that several patient-related characteristics can predict the functional outcome after THA. It shows strong evidence of an association between BMI, age, comorbidity, preoperative physical function and mental health with functional outcome after THA. Weak evidence suggested that quadriceps strength and education were predictive of functional outcomes after THA. Inconsistent evidence was found for the predictors like gender and SES. Alcohol consumption, vitamin D insufficiency and allergies showed limited evidence predicting functional outcome after THA. Understanding predictors will help orthopaedic surgeons and general practitioners predict the outcomes in physical functioning after THA; they can use this information to provide patient-specific advice and target care for patients with THA. Further well-conducted cohort studies are necessary to confirm these findings.

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