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A meta-analysis of prognostic factors in surgical treatment of foot drop due to lumbar degenerative diseases

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ABSTRACT

Objective: Lumbar decompression surgery is an effective treatment for foot drop caused by LDD, but there is controversy about the prognostic factors affecting its efficacy. This study aimed to investigate the factors influencing the surgical outcome of foot drop due to LDD.
Methods: A systematic database search of PubMed, Embase, Web of Science, Cochrane Library and Clinical Trials was performed for relevant articles published until May 2022. Two reviewers independently screened the literature, extracted data, and evaluated the quality of the studies based on the inclusion and exclusion criteria. The quality of the studies was evaluated using the Newcastle-Ottawa Scale (NOS), and STATA 16.0 software was used for meta-analysis.
Results: A total of 730 relevant articles were initially identified and 9 articles were finally included in this study for data extraction and mea-analysis. The results of metaanalysis showed that patients with preoperative moderate muscle strength (2-3/5 on the Medical Research Council scale) had better prognosis compared to those with severe muscle weakness. Additionally, the presence of diabetes mellitus was associated with a poorer prognosis for patients with foot drop due to LDD. The OR values (95%CI) of these two factors were 5.882 (4.449, 7.776) and 5.657 (2.094,15.280) respectively.
Conclusions: Patients with moderate muscle strength have a better prognosis compared to those with severe muscle weakness. The presence of diabetes mellitus is associated with a poorer prognosis for patients with foot drop due to LDD. These factors should be considered when predicting the surgical outcome of foot drop due to LDD.

1. Introduction

Lumbar degenerative diseases (LDD) usually originate from the intervertebral disc, which may cause an instability in the spine segment, and is a common clinical spinal disease.[1,2] LDD mostly affects middle-aged and elderly people and is the main cause of low back and leg pain. Foot drop, characterized by an inability to lift the front foot due to weak dorsiflexor muscles, can result in an unsafe antalgic gait leading to falls. LDD can also lead to foot drop, however, its incidence is relatively rare. Lumbar decompression surgery is considered an effective method for foot drop due to LDD.[3,4] At present, some studies have reported the factors that affect the recovery of foot drop after lumbar decompression surgery, however, there still remains controversial.[5–7] In order to provide reliable evidence for clinical practice, we conducted a meta-analysis to investigate the prognostic factors of foot drop caused by LDD.

2. Materials and methods

2.1. Study selection and inclusion criteria

We conducted a systematic search of the scientific literature on foot drop and performed a meta-analysis of the pooled data from the eligible studies. Case-control studies or cohort studies were searched from PUBMED, EMBASE, Web of Science, Cochrane Library and Clinical Trials independently by two authors. We adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines.[8] Taking PubMed as an example, the specific retrieval strategy is shown as follows ("gait disorders, neurologic" [MeSH Terms] OR ("foot drop" [Title/Abstract] OR "drop foot" [Title/Abstract])) AND ("spondylolysis" [MeSH Terms] OR ("spondylolisthesis" [Title/Abstract] OR

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"spondylolysis" [Title/Abstract]) OR (("Lumbar" [Title/Abstract] AND "degenerati*" [Title/Abstract]) OR "LDD" [Title/Abstract] OR "LUMBAR VERTEBRAE" [MeSH Terms] OR "INTERVERTEBRAL DISC DEGENERATION" [MeSH Terms] OR "lumbar spinal stenosis" [Title/Abstract] OR "lumbar disc herniation" [Title/Abstract] OR "SPINAL STENOSIS" [MeSH Terms])). Two evaluators independently screened the literature by adopting the unified inclusion criteria. In case of any disagreement, it was resolved through discussion or with the assistance of a third researcher.

The eligibility criteria were specified using the Population, Intervention, Criteria, Outcome and Study design (PICOS) framework. The selected literature must meet the following conditions: 1) Foot drop was assessed by determining muscle strength of the tibialis anterior using a manual muscle test (MMT)and by characterizing it according to the Medical Research Council (MRC) scale.[9] In the present study, foot drop should be clearly defined as tibialis anterior muscle strength of lower than grade 4 by manual muscle testing[8]; 2) The original data should provide OR value and 95% confidence interval (95%CI) or the OR value and 95%CI can be calculated from the data; 3) The summary results can be expressed by corresponding statistical indicators.

2.2. Exclusion criteria

Literature meeting one of the following conditions were excluded: (1) animal studies; (2) meta-analysis and reviews; (3) duplicate studies; (4) case reports; (5) articles without available data; (6) unrelated studies.

2.3. Methodological quality evaluation

The Newcastle–Ottawa Scale (NOS) scoring system was used to evaluate the methodological quality of the included studies. The quantitative principle of the star system was adopted, and the full score was 9 stars.

2.4. Statistical analysis

Stata version 16.0 (Stata Corp LP, College Station, Texas) was used to synthesize, summarize, and evaluate the data. The collected data were tested for heterogeneity and the combined OR value and 95%CI were calculated. To determine heterogeneity across the studies, the I^2 Higgins (0–100%) was adopted. The fixed-effect model was used for meta-analysis when the heterogeneity statistic I^2 is less than 50%. In the meanwhile, the random-effect model was applied when the heterogeneity statistic I^2 is greater than or equal to 50%. Funnel plot was used to analyze potential publication bias when the number of articles included was more than 5. Sensitivity analysis was used to test the stability of meta-analysis results: (1) comparison of results between random effect model and fixed effect model; (2) When the number of included literature is more than 5, the points with significant deviation from 95%CI in the funnel chart are excluded for meta-analysis, and the results are compared with those when all the literature are included. The *p* value for statistical significance was set at <0.05.

3. Results

3.1. Study selection

According to the search terms of the literature, a total of 730 relevant articles were initially identified. Of those articles, 205 were duplicated in databases, and 240 were not relevant to the objectives of this study. After screening the remaining 285 articles using titles and abstracts, most of the studies were excluded because they were case reports (240) or meta-analysis and reviews (20). After reading the full text of the remaining 25 articles, a total of 15 were excluded due to the inability to obtain the full text (1), non-English writing (1), animal experiments (7) and insufficient data (7). Finally, 9 articles were included in this study for data extraction and meta-analysis (Fig. 1).[8,10]

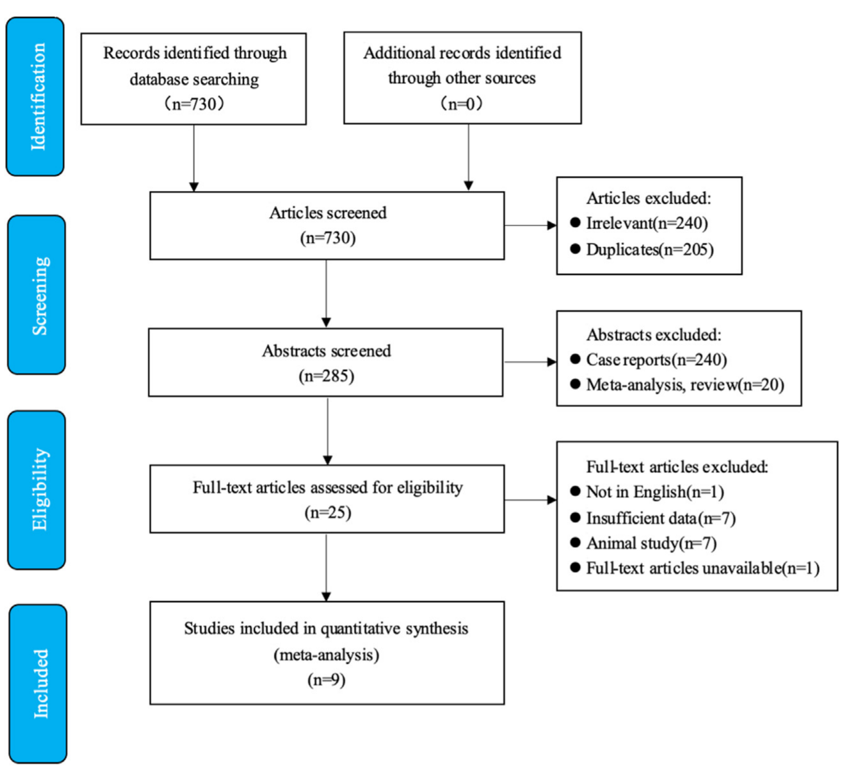

Fig. 1. Flow chart of the searched, identified and included studies for meta-analysis.

3.2. Study characteristics

The eligible studies included 8 retrospective studies and 1 case–control study. The highest NOS score was 8 and the lowest was 5. A total of 792 patients were included in the study, with an average age of 55.09 years, and 57.95% of them were male. The basic characteristics and NOS scores of the included studies are shown in Table 1.

3.3. Meta-analysis

According to the research contents of the included literature and the number of references for each factor, four prognostic factors including duration of foot drop, preoperative muscle strength, age and diabetes mellitus were selected for meta-analysis.

3.4. Duration of foot drop

Taking duration of foot drop as an independent factor, the results of meta-analysis using a random effect model showed that there was no correlation between the duration of foot drop and the recovery of foot drop after lumbar decompression surgery [combined OR values = 0.993, 95%CI (0.936, 1.053), $p = 0.809$, Fig. 2]. In addition, great heterogeneity was found among the studies ($I^2 = 84.4\%$, $p < 0.01$, Fig. 2). Sensitivity analysis of literature was conducted by adopting the one-by-one elimination method, and no studies with a large impact on heterogeneity were found.[11–16]

3.5. Preoperative muscle strength

Six studies reported that the OR value between preoperative muscle strength and foot drop recovery was 4.86 [95%CI (1.649, 14.326)], and there was great heterogeneity between studies ($I^2 = 81.1\%$, $p < 0.01$, Fig. 3A).[11,13–15,17,18] The forest plot between preoperative muscle strength and foot drop recovery is also shown in Fig. 3A. Subgroup analysis was conducted according to the publication time of the eligible literature. There was no heterogeneity among the literature published after 2010($I^2 = 29.6\%$, $p = 0.224$) and preoperative muscle strength significantly affected the recovery of foot drop [combined OR

Table 1
Characteristics and quality evaluation of the included studies.

Author, year	Study design	Date of data collection	Sample(N)	Mean age (years)	Male (N)	Definition of foot drop	Prognostic factors	Statistical method	NOS scores
H. Aono,2007	retrospective study	1993–2001	46	56.6	27	MRC<3	1. Preoperative duration of muscle weakness ($P = 0.004$) 2. Preoperative tibialis anterior ($P = 0.049$)	Logistic regression analysis	6
A. Berger, 2022	retrospective study	2010–2016	40	58.9 ± 17.9	24	MRC<4	1. Preoperative tibialis anterior ($P = 0.018$)	Logistic regression analysis	7
D. Bhargava, 2012	retrospective study	2004–2007	26	48	15	MRC≤3	1. Preoperative duration of muscle weakness ($P = 0.019$)	Logistic regression analysis	5
K. Liu, 2013	retrospective study	2005–2010	135	55	62	MMT≤3	1. Preoperative duration of muscle weakness ($P = 0.0360$) 2. Preoperative tibialis anterior ($P = 0.0064$) 3. Age ($P = 0.0309$)	Logistic regression analysis	7
J. Ma, 2018	retrospective study	2013–2016	236	46.2	134	MRC<4	1. diabetes mellitus 2. acute episode 3. acute-on chronic episode 4. Disc Calcification 5. Recess-Foraminal 6. Canal occupy rate (25%–50%) 7. Canal occupy rate (>50%) 8. Canal AP dimension	Logistic regression analysis	8
S. Masuda, 2020	retrospective study	2012–2017	87	66.9	52	MMT≤3	1. Preoperative duration of muscle weakness ($P = 0.04$) 2. Preoperative tibialis anterior ($P = 0.002$) 3. Age ($P = 0.01$)	Logistic regression analysis	7
S. Takenaka, 2017	retrospective study	1993–2013	102	59	58	MRC<3	1. Preoperative duration of muscle weakness ($P < 0.001$) 2. Preoperative tibialis anterior ($P < 0.001$) 3. Age ($P = 0.014$)	Logistic regression analysis	6
J. Tanaka, 2021	retrospective study	2005–2018	55	61.8	37	MMT<3	1. Preoperative duration of muscle weakness ($P = 0.027$) 2. Radicular leg pain ($P = 0.004$)	Logistic regression analysis	6
V. K. Viswanathan, 2019	Prospective study	2013–2015	65	43.4	50	MRC≤3	1. Preoperative tibialis anterior ($P = 0.028$) 2. Diabetes mellitus ($P = 0.033$)	Logistic regression analysis	7

The Newcastle–Ottawa Scale (NOS); Manual muscle test (MMT); Lumbar degenerative diseases (LDDs).

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           Study        |     ES    [95% Conf. Interval]     % Weight
---------------------+---------------------------------------------------
H. Aono (2007)       |  1.810       1.151     2.847          1.63
D. Bhargava (2012)   |  0.930       0.881     0.981         27.99
K. Liu (2013)        |  2.543       1.063     6.083          0.46
S. Masuda (2020)     |  3.590       1.091    11.812          0.25
S. Takenaka (2017)   |  0.970       0.950     0.990         34.86
J. Tanaka (2021)     |  1.019       0.998     1.041         34.81
---------------------+---------------------------------------------------
D+L pooled ES        |  0.993       0.936     1.053        100.00
---------------------+---------------------------------------------------

  Heterogeneity chi-squared =  32.00 (d.f. = 5) p = 0.000
  I-squared (variation in ES attributable to heterogeneity) =  84.4%
  Estimate of between-study variance Tau-squared =  0.0025

  Test of ES=1 : z=   0.24 p = 0.809
```

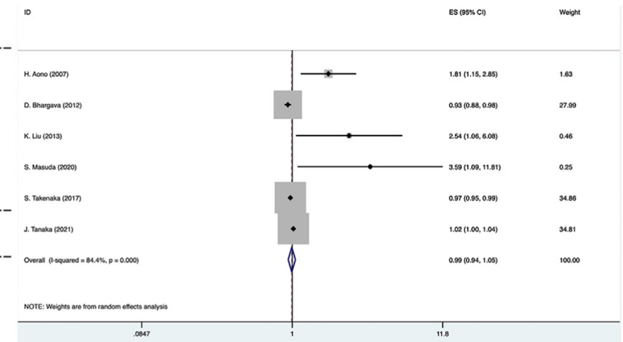

Fig. 2. Multivariate analysis of duration of foot drop in a forest map.

A

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           Study        |     ES    [95% Conf. Interval]     % Weight
---------------------+---------------------------------------------------
H. Aono (2007)       |  0.290       0.082     1.025         17.21
A. Berger (2022)     |  6.800       1.382    33.463         15.11
K. Liu (2013)        |  5.528       4.097     7.458         22.11
S. Masuda (2020)     | 12.000       2.407    59.824         15.03
S. Takenaka (2017)   | 44.500       6.781   292.026         13.38
V. K. Viswanathan (2 |  4.171       1.169    14.884         17.15
---------------------+---------------------------------------------------
D+L pooled ES        |  4.860       1.649    14.326        100.00
---------------------+---------------------------------------------------

  Heterogeneity chi-squared =  26.48 (d.f. = 5) p = 0.000
  I-squared (variation in ES attributable to heterogeneity) =  81.1%
  Estimate of between-study variance Tau-squared =  1.3523

  Test of ES=1 : z=   2.87 p = 0.004
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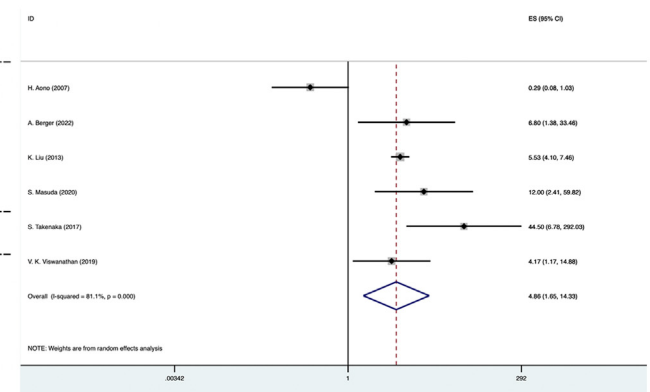

B

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           Study        |     ES    [95% Conf. Interval]     % Weight
---------------------+---------------------------------------------------
A. Berger (2022)     |  6.800       1.382    33.463          3.07
K. Liu (2013)        |  5.528       4.097     7.458         86.90
S. Masuda (2020)     | 12.000       2.407    59.824          3.02
S. Takenaka (2017)   | 44.500       6.781   292.026          2.20
V. K. Viswanathan (2 |  4.171       1.169    14.884          4.81
---------------------+---------------------------------------------------
I-V pooled ES        |  5.882       4.449     7.776        100.00
---------------------+---------------------------------------------------

  Heterogeneity chi-squared =   5.68 (d.f. = 4) p = 0.224
  I-squared (variation in ES attributable to heterogeneity) =  29.6%

  Test of ES=1 : z=  12.44 p = 0.000
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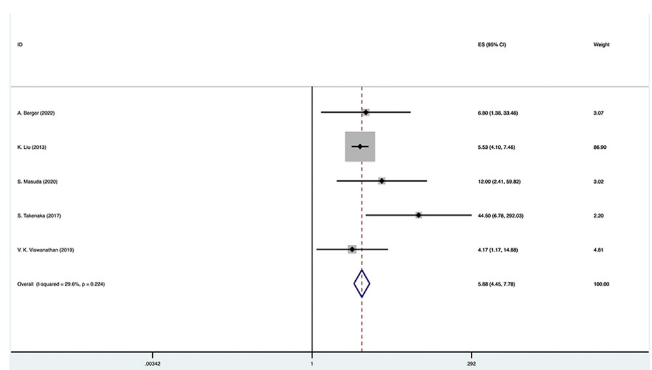

Fig. 3. A: Multivariate analysis of preoperative muscle strength in a forest map. B: Subgroup analysis of preoperative muscle strength in a forest map.

values = 5.882, 95%CI (4.449, 7.776), $p < 0.01$, Fig. 3B].

3.6. Age

Three studies reported the relationship between age and postoperative foot drop recovery.[13–15] There was moderate heterogeneity among these studies ($I^2 = 62.6\%$, $p = 0.069$), therefore the random effect model was used to statistically analyze the data. The results showed that age was not a factor affecting postoperative foot drop recovery, and the difference had no statistical significance [OR = 0.934, 95%CI (0.852, 1.023), $p = 0.142$, Fig. 4].

3.7. Diabetes mellitus

Meta-analysis of the two included studies using fixed effect model showed that diabetes mellitus had a significant effect on the recovery of foot drop after lumbar decompression surgery [OR = 5.657, 95%CI (2.094,15.280), $p = 0.001$, Fig. 5] and no heterogeneity was observed between the two studies ($I^2 = 0\%$, $p = 0.994$).[18,19]

3.8. Publication bias analysis

The scatter points in the funnel plots of duration of foot drop and

Study	ES	[95% Conf. Interval]		% Weight
K. Liu (2013)	3.208	1.113	9.243	0.74
S. Masuda (2020)	0.930	0.876	0.987	50.69
S. Takenaka (2017)	0.920	0.862	0.982	48.57
D+L pooled ES	0.934	0.852	1.023	100.00

Heterogeneity chi-squared = 5.35 (d.f. = 2) p = 0.069
I-squared (variation in ES attributable to heterogeneity) = 62.6%
Estimate of between-study variance Tau-squared = 0.0034

Test of ES=1 : z= 1.47 p = 0.142

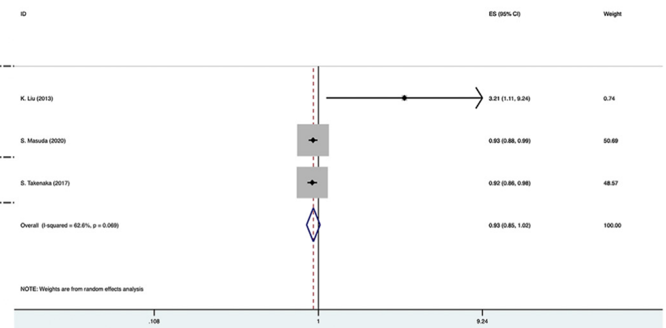

Fig. 4. Multivariate analysis of age in a forest map.

Study	ES	[95% Conf. Interval]		% Weight
J. Ma (2018)	5.640	1.583	20.101	61.14
V. K. Viswanathan (2	5.683	1.154	27.982	38.86
I-V pooled ES	5.657	2.094	15.280	100.00

Heterogeneity chi-squared = 0.00 (d.f. = 1) p = 0.994
I-squared (variation in ES attributable to heterogeneity) = 0.0%

Test of ES=1 : z= 3.42 p = 0.001

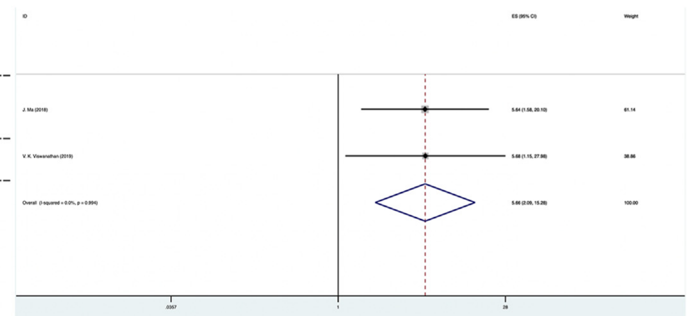

Fig. 5. Multivariate analysis of diabetes mellitus in a forest map.

preoperative muscle strength were symmetrically distributed, suggesting that there was no publication bias. Using duration of foot drop , preoperative muscle strength and age as indicators to detect publication bias, the Egger's and Begg's test results are as follows: 1) duration of foot drop (0.284, 0.707); 2) preoperative muscle strength (0.891, 0.260); 3) age (0.110, 1.000). The above test results are all $p > 0.05$, indicating that there is little possibility of publication bias in the current meta-analysis.

4. Discussion

This study systematically collected the relevant studies on the influencing factors of postoperative recovery of foot drop caused by LDD. A total of 9 articles were included, and the inclusion and exclusion criteria were clearly specified. The statistical methods were correctly used, and the literature quality was relatively high (all≥5 stars). Therefore, the meta-analysis results are highly reliable, indicating that preoperative muscle strength and diabetes mellitus are closely related to the recovery of foot drop. In addition, duration of foot drop and age were not significantly related to the prognosis of foot drop.

The results of this study indicate that surgical decompression is effective in improving motor weakness in foot dorsiflexion. Meta-analysis showed that patients with moderate weakness (MMT grade 2–3) or without diabetic comorbidities had better clinical outcomes. However, it is surprising that earlier surgery (< 4 weeks) or younger age did not result in statistically significant improvement in muscle strength after surgery, which is inconsistent with previous meta-analysis conclusions.

The meta-analysis conducted by Saeed F et al[8] indicated that earlier surgery (<6 weeks) and younger age (<50 years) were strong predictors of surgical outcome. However, patients with painless foot drop and those underwent lumbar fusion surgery were excluded from this study, which led to a decrease in the number of included studies. We believe that this may be the reason for the inconsistent conclusions between the two studies. Previous studies have confirmed that surgical intervention for patients with painless foot drop can contribute to the improvement of neurological function and might help patient recover back to a normal and active lifestyle.[20,21] Lumbar fusion surgery has been widely used in the surgical treatment of LDD, especially for patients with neurological impairment due to lumbar spondylolisthesis and lumbar spinal stenosis. In contrast to decompression alone, it has the advantage of a wider decompression range and is more beneficial for restoring spinal cord morphology and improving neural function. Based on the above considerations, we included patients with painless foot drop and those underwent lumbar fusion surgery in the meta-analysis to enhance the reliability of the study.

The effect of duration of preoperative muscular weakness on neurological recovery is controversial.[22] Some studies have demonstrated that the duration has no effect on surgical outcome.[23,24] The reasons for this controversy are complex. The duration of preoperative weakness is determined by the patient's medical history, so it is prone to error. In addition, there is no unified standard for the optimal duration of weakness before surgical treatment, which also affects the postoperative recovery.

The relationship between age and postoperative neurological recovery is not clear. Aono et al[11] reported that the increase of age at the time of operation had an adverse effect on the recovery of postoperative muscle strength. Ghahreman et al[22] reported that patients aged 25 to 40 recovered better than patients aged 41 to 60, and they also recovered better than patients aged over 60. Other studies have shown that there is no significant correlation between age and recovery of muscular weakness after surgery.[23,25,26]

5. Conclusion

Currently, studies examining the factors influencing the prognosis of foot drop caused by LDD have produced conflicting results, with no consensus view established. To address this issue, we conducted a meta-analysis to identify prognostic factors in patients undergoing lumbar decompression surgery for foot drop. Our findings suggest that patients with moderate preoperative muscle strength (MMT grade 2–3) or without diabetes have a better prognosis. However, contrary to the control group, cases with a shorter duration of muscular weakness or younger age did not achieve a better clinical outcome.

CRediT authorship contribution statement

Yang Hou: Conceptualization, Writing – original draft, Writing – review & editing. **Lei Liang:** Data curation, Formal analysis, Investigation. **Tianyi Zhao:** Investigation, Methodology. **Hongyang Shi:** Software. **Haoyang Shi:** Data curation. **Jiangang Shi:** Supervision. **Guodong Shi:** Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that there are no conflict of interests

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