Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and interrater reliability of a clinical tool for patients with cerebral palsy

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LIST OF ABBREVIATIONS

CST	Corticospinal tract
ICC	Intraclass correlation coefficient
PWM	Periventricular white matter
SCALE	Selective Control Assessment of the Lower Extremity
SVMC	Selective voluntary motor control

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Normal selective voluntary motor control (SVMC) can be defined as the ability to perform isolated joint movement without using mass flexor/extensor patterns or undesired movement at other joints, such as mirroring. SVMC is an important determinant of function, yet a valid, reliable assessment tool is lacking. The Selective Control Assessment of the Lower Extremity (SCALE) is a clinical tool developed to quantify SVMC in patients with cerebral palsy (CP). This paper describes the development, utility, validation, and interrater reliability of SCALE. Content validity was based on review by 14 experienced clinicians. Mean agreement was 91.9% (range 71.4–100%) for statements about content, administration, and grading. SCALE scores were compared with Gross Motor Function Classification System Expanded and Revised (GMFCS-ER) levels for 51 participants with spastic diplegic, hemiplegic, and quadriplegic CP (GMFCS levels I – IV, 21 males, 30 females; mean age 11y 11mo [SD 4y 9mo]; range 5–23y). Construct validity was supported by significant inverse correlation (Spearman's r=-0.83, p<0.001) between SCALE scores and GMFCS levels. Six clinicians rated 20 participants with spastic CP (seven males, 13 females, mean age 12y 3mo [SD 5y 5mo], range 7–23y) using SCALE. A high level of interrater reliability was demonstrated by intraclass correlation coefficients ranging from 0.88 to 0.91 (p<0.001).

Children with spastic cerebral palsy (CP) exhibit multiple impairments that contribute to functional motor deficits. Although spasticity and contractures may be more obvious impairments, underlying deficits in selective motor control can negatively affect function to a greater degree.[1,2] Assessment of selective motor control in lower extremities in patients with CP has received little attention, despite growing support for it as a predictive factor of functional ability.[1–4]

Selective motor control has been defined as '... the ability to isolate the activation of muscles in a selected pattern in response to demands of a voluntary movement or posture.'[5] The term 'selective voluntary motor control' (SVMC) differentiates the deliberate performance of isolated movements upon request from habitual selective muscle activation during functional tasks, such as walking. Voluntary movement is produced through the corticospinal tracts (CSTs), which control both directionality and force production.[6] Damage to the CSTs interferes with the force, speed, timing, and pattern of volitional movements.[7] Injury to CSTs within the periventricular white matter (PWM) has been correlated with motor disability in CP.[8] Damage to PWM was the most common finding in brain scans of children with spastic diplegia, and was

present in more than one-third of those with hemiplegia and quadriplegia.[9]

Evidence of SVMC impairment in CP has been shown. Timing errors in muscle recruitment during attempted maximal voluntary contractions exemplify the inability to recruit an individual muscle group selectively without inappropriate antagonist muscle activity.[10] In addition, simultaneous associated movements at contralateral joints, for example mirror movements, have been described.[11] Mass patterns of flexion and extension, which have historically been referred to as 'synergies,' are seen in the absence of SVMC.[12] In patients with CP, these flexor and extensor patterns of the lower extremities are described as persistence of the immature patterns observed during typical infant kicking[13] and stepping.[14] Tightly coupled hip, knee, and ankle movements occur in term and preterm infants with and without damage to white matter. These movements become disassociated or uncoupled over time in infants without brain lesions, but persist in preterm infants with damage to white matter.[13] These mass movement patterns are observed and have been measured using electromyography during gait and voluntary movement in children and adults with CP.[12,14–16]

Clinical examinations of SVMC in children with CP have been described,[2,3,17–19] but a detailed tool to evaluate the entire lower limb has not been validated. Assessments vary as to the joint(s) tested, positions used, task(s) required, and grading criteria. Staudt and Peacock[3] used SVMC as a prognostic factor when selecting candidates for selective posterior rhizotomy. These examination methods were further developed by Fowler et al.[18] as a measure of severity to select and categorize participants in a randomized controlled trial. Grading was limited to knee and ankle joints with an overall limb classification of 'good', 'fair', or 'poor' SVMC. Mirror movements, reciprocation, and speed were not considered. Boyd and Graham[17] introduced a 0- to 4-point scale to assess ankle dorsiflexion after botulinum toxin injections of the plantar flexors. Examiners were required to identify visually which muscles were the primary or secondary movers. This test was called 'selective motor control of dorsiflexion'. Others have described it as a measure of CST function,[20] although SVMC does not appear to be the primary focus. Specific muscles used to achieve dorsiflexion took precedence over the use of mass patterns in the scoring. Although others have graded mass limb flexion during dorsiflexion as the lowest level of SVMC,[2,19] this test graded total limb flexion higher than recruitment of accessory muscles (toe extensors). Substitution of toe extensors during dorsiflexion may occur in the presence of plantar flexor contractures or tibialis anterior weakness and may not indicate SVMC impairment. Validation of the 'selective motor control of dorsiflexion' test could not be found in the literature, and a wide range of interrater reliability was reported.[20] Valid and reliable tests have been developed for assessment of recovery stages in adults after stroke,[21,22] but they are not ideal for patients with CP. Administration includes practice on the 'non-affected side' and testing in standing, which limits applicability for patients with bilateral lower-extremity involvement and interferes with observation of mirroring.

A valid, reliable assessment method that has clinical utility is needed for SVMC assessment of the entire lower extremity in patients with spastic CP. The purpose of this paper is to describe the development of a clinical tool entitled Selective Control Assessment of the Lower Extremity (SCALE) and present evidence of its validity and interrater reliability.

METHOD

Participants were individuals with spastic CP and clinicians. Clinicians participating in content validation were recruited from physical therapy clinics, hospitals, and universities. Participants with CP were recruited from the UCLA/Orthopaedic Hospital Center for Cerebral Palsy. The institutional review board at this institution approved the study. Informed consent was obtained from all participating clinicians, and informed assent/consent was obtained from all participants with CP and/or their parent or legal guardian.

The SCALE tool

The SCALE tool was designed for clinical administration and scoring by healthcare professionals, to be used in less than 15 minutes without specialized equipment. The tool includes 'Directions for Administration,' 'Instructions for Grading,' and a 'Score Sheet.' Hip, knee, ankle, subtalar, and toe joints are assessed bilaterally. One representative reciprocal movement that varies from the mass flexor/extensor patterns is chosen to assess SVMC for each joint. Evaluations are performed in the sitting position, except for hip flexion, which is tested in the side-lying position to allow for adequate joint excursion. Sitting and side-lying positions allow evaluation of patients who are unable to stand, permit observation of contralateral limb movements, and enable the patient to visualize their limb in case of proprioceptive deficits. The following factors were used to develop the assessment and grading criteria: (1) ability to move each joint selectively; (2) involuntary movement at other joints including the contralateral limb; (3) ability to reciprocate movement; (4) speed of movement; and (5) generation of force as demonstrated by excursion within the available range of motion. These were based on components of CST function described in the lit-

erature[7] and methods of motor control assessment that have been used historically.[12,21]

For each joint, the examiner first demonstrates the task by passively moving the limb through the desired movement sequence using a three-second verbal cadence. The approximate passive range of motion is noted for comparison with the observed range during the patient's active effort. The patient is then asked to perform the desired motion at approximately the same speed without moving other joints of the extremity being tested or the contralateral limb. If unsuccessful, feedback is provided and additional attempts are allowed.

The hip assessment is performed with the patient in side-lying position. The examiner supports the weight of the limb but does not assist the movement. The patient is asked to flex, extend, and flex the hip while maintaining the knee in extension. This movement pattern was chosen over hip extension because it was easier for patients to perform as they could easily visualize their limb. For patients with severe hamstring tightness, the ability to extend the hip with the knee flexed can be used as an alternative test.

The remainder of the assessment is performed in the sitting position. The patient is asked to perform the following movement patterns: knee extension and flexion; ankle dorsiflexion and plantar flexion with the knee extended; subtalar inversion and eversion; and toe flexion and extension in a reciprocating pattern to a verbal cadence (e.g. 'flex, extend, flex'). SVMC is graded at each joint as 'Normal' (2 points), 'Impaired' (1 point), or 'Unable' (0 points).

A grade of 'Normal' is given when the desired movement sequence is completed within the verbal count without movement of untested ipsilateral or contralateral lower extremity joints. A grade of 'Impaired' is given when the patient isolates motion during part of the task, but demonstrates any of the following errors: movement occurs in only one direction; observed movement is less than 50% of the approximate available passive range of motion found during the passive demonstration; movement occurs at a non-tested joint (including mirror movements); or the time for execution exceeds the approximate 3-second verbal cadence. A grade of 'Unable' is given when the requested movement sequence is not initiated or when it is performed using a synergistic mass flexor or extensor pattern. A synergistic mass movement pattern is defined as a simultaneous, obligatory flexor or extensor pattern at two or more joints.[23,24] If the patient does not initiate the requested movement sequence, extensor and flexor synergy patterns may be elicited using manual resistance to verify muscle force-generating capacity. A SCALE score for each limb is obtained by summing the points assigned to each joint for a maximum of 10 points per limb.

Content validity

Content validity is '... the extent to which a measure is a complete representation of the concept of interest' and is established by evaluation of the instrument by knowledgeable peers.[25] Content validity of the SCALE tool was established using written feedback from 14 expert clinicians. Expert clinicians were defined as those having 10 or more years of experience in evaluating patients with CP (experience range 10–40y, mean: 21y 2mo). They included 12 physical therapists, one occupational therapist, and one physician. Clinicians participated in an educational session that included an overview of test administration using videos or photographs of patients. They were provided with written procedures and the prototype SCALE tool. Participants were given an opportunity to ask questions and completed a written feedback form containing 32 statements about the tool design (Table I). For each statement, participants were asked to check 'agree', 'disagree',

Table I: Selective Control Assessment of the Lower Extremity (SCALE) expert feedback form statements

Each of 32 statements was rated as Agree, Disagree, or Undecided

Statements rated for each of five tests: hip, knee, ankle, subtalar, and toe joints (20 statements)

1. The position used is optimal for assessment of the desired motion.
2. The instructions for the patient are clear.
3. The movements requested/demonstrated are appropriate to determine the selective motor control for the joint(s).
4. The support or assistance given to the patient is appropriate for the test.

Statements rated for grading (seven statements)

1. The speed is appropriate (within three-second verbal cadence).
2. The range of motion required for the tests is appropriate to adequately differentiate between scores of Normal, Impaired, and Unable.
3. The criteria are clear to adequately differentiate between scores of Normal, Impaired, and Unable.
4. The grades Unable and Impaired are clearly distinguishable.
5. The descriptions provided to elucidate the difference between grades of Unable and Impaired are adequate.
6. The grades Normal and Impaired are clearly distinguishable.
7. The descriptions provided to elucidate the difference between grades of Normal and Impaired are adequate.

Statements rated for overall test (five statements)

1. The order of test administration is appropriate.
2. The inclusion of a resisted flexor synergy pattern is needed or useful.
3. The inclusion of a resisted extensor synergy pattern is needed or useful.
4. The Total Limb Score is needed or useful.
5. The Total Limb Score categories are appropriately distributed.

or 'undecided'. If they disagreed or were undecided, they were asked to provide an explanation and suggest changes. The frequency of each response was obtained for all statements. A minimum of 90% 'agree' responses was set for the content covered in each statement to be accepted without amendments to the SCALE tool. Amendments to the preliminary version of SCALE were made based on expert feedback.

Interrater reliability

The interrater reliability of clinical administration and scoring of SCALE was performed by two groups of three trained raters for 20 participants with spastic CP. The six raters included three physical therapists, one pediatrician, one pediatric neurologist, and a pediatric orthopedic surgeon with a range of 1 to 29 years of experience in assessing patients with CP. Standardized training on the administration and scoring of SCALE was provided. To participate as a rater, clinicians were required to score 20 videotaped examples (four for each of the five joints) with an accuracy of 90% or higher and demonstrate appropriate test procedures during a practice examination.

To minimize potential patient fatigue, consecutive assessments were limited to three. Therefore, the six clinicians were divided into two teams (A and B), each containing three raters. Team A raters performed SCALE examinations on 10 participants with CP, and Team B examined 12 (Table II). The raters assessed the patients in random order and there was no communication among them about scores. Intraclass correlation coefficients (ICCs) and corresponding 95% confidence intervals (CIs) were calculated for the SCALE scores obtained for left and right limbs separately for each team.

Table II: Characteristics of participants for interrater reliability

	Total[a] (*n*=20)	Team A (*n*=10)	Team B (*n*=12)
Age (y:mo)			
Mean (SD)	12:3 (5:5)	10:4 (3:11)	13:7 (5:10)
Range	7:0–23:0	7:0–17:6	7:0–23:0
Sex (n)			
Female	13	6	9
Male	7	4	3
Distribution of impairment (*n*)			
Diplegia	16	8	9
Hemiplegia	3	1	3
Quadriplegia	1	1	0
GMFCS level (*n*)			
I	3	1	3
II	6	4	3
III	8	3	5
IV	3	2	1

[a]Two participants were evaluated by both teams of raters. GMFCS, Gross Motor Function Classification System.

Construct validity

According to Sim and Arnell,[26] '... evidence of construct validity can be gained by seeking a positive correlation between measures of the original concept and those of other concepts to which the original concept is known to be positively related.' Construct validity of SCALE was evaluated by determining the relationship between SCALE scores and an independent assessment of function using the expanded and revised edition of the Gross Motor Function Classification System (GMFCS-ER).[27,28] This is a five-level system that stratifies the severity of mobility impairment up to the age of 18 years. Level I represents the highest level of mobility, and level V the lowest. For participants aged 19 years and older, the 13- to 18-year-old age band was used to determine the level. Although SCALE and the GMFCS measure different aspects of a patient's disability, individuals with higher SCALE scores would be expected to have less overall impairment of lower extremity function, resulting in a higher mobility level (indicated by a lower GMFCS level).

Fifty-one individuals with spastic CP in GMFCS levels I to IV, participated (Table III). Ten individuals with CP at GMFCS level V were screened for participation, but none were enrolled owing to one or more of the following factors: diagnosis of dyskinetic or mixed spastic/dyskinetic CP; inability to consent to participate; or inability to follow a simple motor direction. The SCALE assessment was administered by one of two experienced therapists who participated in the interrater reliability trials. Right and left

Table III: Characteristics of participants for construct validity (*n*=51)

Age (y:mo)	
Mean (SD)	11:11 (4:9)
Range	5:1–23:0
Sex (*n*)	
Female	30
Male	21
Distribution of impairment (*n*)	
Diplegia	35
Diplegia with hemiplegic overlay	5
Hemiplegia	6
Quadriplegia	5
GMFCS level (*n*)	
I	10
II	12
III	19
IV	10

GMFCS, Gross Motor Function Classification System.

SCALE scores were summed for each participant as an overall representation of lower extremity SVMC ability for comparison with GMFCS levels. Spearman's rank correlation coefficients were computed to examine the relationship between the scores. All statistical analyses used JMP version 6.0 (SAS, Cary, NC, USA) and SPSS version 15.0, (SPSS, Chicago, IL, USA).

RESULTS

Content validity

Responses from expert clinicians were tabulated and the percentage agreement was determined for each statement individually and for the total group of responses. Of the total of 448 potential responses from all clinicians, 18 (4%) were blank and not included in subsequent analyses. There were 395 responses indicating 'agreement' with the tool (91.9%; range 71.4–100%; Table IV).

Twenty-four of the 32 statements rated by the experts met the 90% agreement criterion and no change was made to the corresponding items on the SCALE tool. To meet the 90% criterion, there could be no more than one 'undecided' or 'disagree' response. Eight of the 32 statements did not reach our minimum of 90% agreement (Table IV). For these statements, at least two experts responded with either 'undecided' or 'disagree'. 'Undecided' was chosen more frequently than 'disagree' (16 responses versus 5). Explanations and suggestions associated with these statements were critically examined and modifications to the SCALE tool were made.

No suggestions or explanations were offered for statements related to position or grading for testing at the knee; therefore the associated SCALE items were not revised. Some experts recommended that additional assessment of hip extension with knee flexion be included. We chose only one movement sequence per joint to limit complexity and time requirements of SCALE. The option for use of an alternative hip extension test was clarified in the 'Directions for Test Administration.' Two experts questioned the examiner's support of the limb during the hip test. Although use of a device such as a powder board would eliminate potential examiner influence, it is not practical in most clinical environments. Use of a supported standing position was suggested, but not implemented, because it would preclude use of the tool for severely affected patients and would interfere with observation of mirroring. Concern was expressed that the target population might not comprehend the ankle movement sequence instructions, so the patient instructions were simplified and made more universally understandable. We clarified that the script is suggested rather than mandatory, and that modifications may be made to elicit optimum performance. Although some experts checked 'undecided' or 'disagree' for inclusion of resisted flexor and extensor synergy patterns, others included strong written support of these components. Confirming the patient's ability to move actively in the mass flexor/extensor patterns was considered to be an essential component of the clinical examination by the SCALE developers and several experts. Although two experts questioned the usefulness of a total limb score, one of them acknowledged its value for research. Experts commented on the overall clinical usefulness and ease of administration of SCALE. The revised SCALE tool incorporating all changes is presented in Appendix SI (supporting information, published online).

Interrater reliability

The reliability testing showed relatively high ICCs. ICCs and 95% CIs for the left and right limbs for both teams of

Table IV: Summary of expert responses

	Number of responses			
	Agree	Undecided	Disagree	Blank
Summary of responses to all 32 statements	395	23	12	18
Eight statements with less than 90% agreement:				
Hip: The movements are appropriate to determine SVMC	10	2	1	1
Hip: Support or assistance given to patient is appropriate	12	2	0	0
Knee: Position used is optimal to assess desired motion	11	3	0	0
Ankle: The instructions for the patient are clear	12	1	1	0
Grading: 'Unable' and 'Impaired' are clearly distinguishable	12	2	0	0
Inclusion of a resisted flexor synergy pattern is needed or useful	11	2	1	0
Inclusion of a resisted extensor synergy pattern is needed or useful	10	3	1	0
The total limb score is needed or useful	12	1	1	0

SVMC, selective voluntary motor control.

Table V: Interrater reliability of SCALE

Group	Limb	ICC	95% CIs	*p* value
A	Left	0.88	0.69, 0.97	<0.001
A	Right	0.89	0.72, 0.97	<0.001
B	Left	0.90	0.77, 0.97	<0.001
B	Right	0.91	0.79, 0.97	<0.001

SCALE, Selective Control Assessment of the Lower Extremity.

raters are presented in Table V. ICCs ranged from 0.88 to 0.91 and all were significant at $p<0.001$.

Construct validity

SCALE scores were significantly inversely correlated with GMFCS levels (Spearman's rank correlation coefficient= –0.83, $p<0.001$). The mean SCALE score declined from 15.0 for participants at GMFCS level I to 3.1 for participants at GMFCS level IV (Fig. 1). SCALE scores showed a clear downward trend; however, scores for participants at GMFCS level III showed considerable overlap in range with participants at levels II and IV.

DISCUSSION

These results support content validity, construct validity, and interrater reliability of the SCALE tool. Content validity was substantiated by strong overall agreement among 14 expert clinicians and feedback was used for amendments and clarifications to the tool. Construct validity of SCALE was demonstrated by significant correlation with another severity measure, the GMFCS. Because SVMC is only one factor affecting functional mobility, a perfect correlation between these two assessments was not expected. Impairments such as balance, spasticity, contractures, bone and joint deformity, weakness, obesity, or de-conditioning are other contributing factors that may explain the wider range of scores obtained for patients requiring hand-held mobility devices for walking (GMFCS level III). For example, the individual with highest SCALE score within GMFCS level III (Fig. 1) had vision impairment. Although he could walk short distances without assistance, he routinely used a walker. The participant with the lowest SCALE score at GMFCS level III relied on good upper-body strength and was able to ambulate using a walker, despite lack of lower extremity SVMC. We found that SCALE assessment for individuals assigned to GMFCS level V was not feasible as most had a predominant motor disorder of dyskinesia rather than spasticity, and many were unable to follow motor commands.

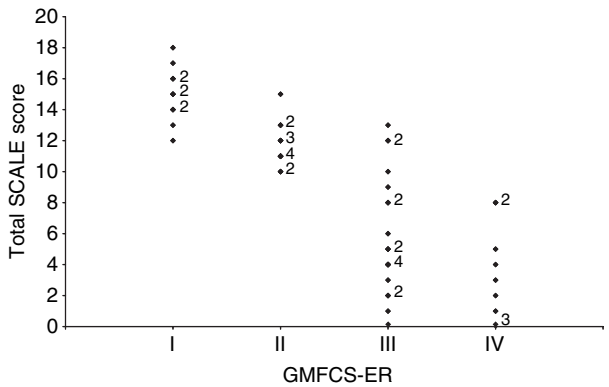

Figure 1: Relationship between total Selective Control Assessment of the Lower Extremity (SCALE) scores (sum of left and right) and Gross Motor Function Classification System - Expanded and Revised version (GMFCS-ER) levels (n=51). Numerals to the right of symbols indicate the number of participants who share the same data point. Spearman's rank correlation coefficient = –0.83, $p<0.001$.

Interrater reliability of clinical assessments was high among six raters representing four different clinical specialties with a wide range of experience. Not all differences among scores can be attributed to raters because performance of patients on repeat testing may vary with practice, boredom, or fatigue. Because of this, only three consecutive assessments were performed. Videotaped assessment could have been used to increase the number of raters assessing a single testing session; however, this study was designed to evaluate reliability of both administration and scoring as would occur in a clinical setting.

Clinical utility is supported by both expert assessment and high interrater reliability. SCALE is detailed yet simple enough for expedient examination of patients with a wide range of physical and intellectual impairments. It requires minimal training, can be performed within 10 to 15 minutes, and does not require equipment. Because the ability to follow simple motor commands is necessary, it is least suitable for patients under 4 years of age and those with severe motor and intellectual impairments (GMFCS V). Although scoring may not be possible for these patients, SVMC can be described based on observations of spontaneous movements. In our experience, patients classified at GMFCS level V were more likely to have dyskinesia, which SCALE was not designed to address. Although designed for use in CP, SCALE may be useful for assessment of patients with other types of neurological involvement such as hereditary spastic paraparesis, traumatic brain injury, multiple sclerosis, or stroke.

CONCLUSION

Evidence for construct and content validity is presented here as the first step in the validation of SCALE. Recent work has shown that SCALE scores are correlated with

laboratory measures of intersegmental coordination during gait,[29] further supporting its validity. This study demonstrated high interrater reliability of the SCALE total limb scores. Ongoing research is examining SVMC impairment at individual joints. Studies of intrarater, test–retest reliability, and long-term stability of SCALE scores are underway. SVMC assessment is believed to be most important for use as a prognostic indicator for treatment planning. As there is a wide range of responses to various treatments in this population of patients, SVMC ability may guide the selection of medical, surgical, or rehabilitative interventions. Introduction of SCALE should provide a meaningful and universal tool for clinicians and researchers.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SI: SCALE: Selective Control Assessment of the Lower Extremity.

This material is available as part of the online article from http://dx.doi.org/10.1111/j.1469-8749.2008.03186.x (this will link you directly to the article).

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This timely book is an essential tool in the clinician's fast changing therapeutic armamentarium. It is both small and useful enough to warrant being carried around by a practitioner as it is very relevant to all professionals who work with children and adolescents.

The book is organized into 10 chapters, with manageable sections designed to support evidence-based best practice. Compared with similar books, it is mid-range in price. It provides excellent value by demystifying the science underpinning cutting edge psychopharmacotherapy, whilst its 'clinical pearls' provide memorable take-home messages.

The experts cover developmental aspects vital in understanding fundamental differences between paediatric and adult psychopharmacology and common pitfalls in the area. The chapter on attention-deficit–hyperactivity disorder provides a timely overview of current potential safety concerns around stimulant prescribing. It does so in a very sensible manner. More emphasis on non-pharmacological interventions as adjuncts would have been welcome given more space. Disruptive behaviour disorders and aggression are considered in a holistic manner whilst reminding clinicians of the need for children and parents to be empowered to take personal responsibility. The anxiety and depression chapters helpfully cover combination treatments with cognitive behaviour therapy, as well as paediatric-specific research on suicidality. All of which will prove reassuring to prescribers and patients alike.

A chapter on bipolar disorders provides a very practical approach to managing adverse effects and deft handling of this potentially contentious area. Multimodal treatment research in the field of autistic spectrum disorders provides gratifying clarity with an excellent target symptom algorithm. Tic disorders and their common comorbidities are skilfully discussed.

The chapter dealing with schizophrenia and psychosis provides very practical management tips for side effects. Further discussion about metformin and statins as potential treatments for hyperglycaemia and hyperlipidaemia arising from atypical antipsychotics would also have been welcome.

The last chapter on disorders seen in general medical settings commends this book to a wider medical readership. It considers sleep disturbance, delirium, and a range of common medical conditions with psychiatric sequelae.

This comprehensive manual will empower practitioners to join up research with best practice. Thus it promotes both a more critical and a more thoughtful approach to intelligent prescribing.

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